SPACE & SIGHT

The perception of space and shape in congenitally blind patients, before and after operation

M. von Senden

with an appendix containing essays by Professor A. Riesen, G. J. Warnock, and Professor J. Z. Young

THE FREE PRESS

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TRANSLATED BY PETER HEATH

A number of cases are on record of persons born blind, or blinded in early childhood, who have later recovered their sight. The peculiar experiences of such patients and their difficulties in learning to see, are both interesting in themselves and of special importance to psychologists, physiologists and philosophers. Much controversy has revolved, for instance, about whether the congenitally blind have any true awareness of space, and whether the newly-sighted can recognise the visual shapes of objects previously known to them only by touch. Unfortunately discussion of such questions has suffered owing to want of knowledge of the evidence available, much of this lies buried in inaccessible journals, and the original aim of the present book was to collect and organise this material and to subject it to critical scrutiny. First published in German some years ago, the book itself, though often alluded to by specialists, has long been unobtainable. It now reappears in an English version, approved by the author himself and differing from the original only by the addition of new bibliographical material and an appendix containing essays by Professor A. Riesen, Mr G. J. Warnock, and Professor J. Z. Young on the implications to their respective fields of psychology, philosophy and physiology.

The author was born in Hamburg and gained his D.Phil. degree at Kiel University. He spent some years as a psychologist in the German Navy. His interest in the subject of this book dates from his friendship with the blind psychologist Dr Wilhelm Ahlmann.

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THE PERCEPTION OF SPACE AND SHAPE
IN THE CONGENITALLY BLIND
BEFORE AND AFTER OPERATION

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Translated by
PETER HEATH

With Appendixes by
A. H. RIESEN, G. J. WARNOCK
and J. Z. YOUNG

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TRANSLATOR'S NOTE

I am indebted to the author for a number of corrections and improvements to the text; to Mr B. R. Singer of St Andrews University for the same service, and for compiling the Select Bibliography; and to Mrs F. Broadie for typing the manuscript.

P. L. H.

PREFACE TO THE ENGLISH EDITION

The Second World War was not only responsible for enormous material damage; it also did great harm to the cause of learning. Apart from the destruction of irreplaceable old manuscripts, it brought unexpected disaster to many a new book as well. Thus it was that in 1943 an air-raid on Leipzig sent up almost the entire stock of the publishers J. A. Barth in flames, with the result that suddenly there was not a single further copy of my book to be had. My transcripts of the original documents concerning operations on the congenitally blind, deposited by me in the Psychological Institute of Kiel University, were similarly destroyed by fire.

It was all the more gratifying, therefore, when six years ago I received from England – where Molyneux first drew attention to these cases in 1690, and where the earliest and now classic reports of Ware, Home and Wardrop were published – an inquiry as to my willingness to sanction an English translation of my book. I naturally agreed at once; having hopes that thereby my work might yet be of service to some case of congenital blindness still to be operated on, and might produce some further contributions to the theory of our ideas of space.

Such cases have actually become very rare, since in many countries nowadays it is the duty of every doctor to notify the health authorities whenever he delivers a blind infant into the world. Thus every attempt to enable such children to see is made at so early an age that it can tell us nothing about the problems of spatial perception, etc., with which we are concerned. My endeavours to supplement the case-list at the end of the book have therefore met only with very limited success. And even so, there are several cases of such patients recovering their sight which are still of no interest to us, since the process of learning to see has not been described in detail.

The case of a fifty-two-year-old patient, operated on by Mr Hirtenstein in Wolverhampton at the end of 1958, is therefore of special importance, and it is to be hoped that the press reports appearing at that time may yet be supplemented by the work of a trained psychologist.

The present English edition of my book would undoubtedly never

have come about but for Miss Sylvia Schweppe of the British Museum. She recognized my work as a source-book for psychology, physiology and philosophy, and set about with the greatest energy and persistence to find a suitable translator and a willing publisher. In this enterprise, which took more than six years, she met and overcame numerous obstacles, and I would like at this point to thank her and pay tribute to her work.

It was her idea, also, to invite three well-known scholars to assess the relevance of my work to their particular subjects and so to provide a wider field of interest for the student. I should therefore like to thank Professor J. Z. Young of the Department of Anatomy, University College, London, Professor Austin H. Riesen, Department of Psychology, the University of Chicago, and Mr. G. J. Warnock, Fellow of Magdalen College, Oxford, for their most valuable contributions.

It was particularly difficult to find a translator, at home in both languages, and also possessing a special knowledge and understanding of the problems dealt with in my book. I was therefore very pleased when, after numerous unsuccessful attempts by other translators, Mr Peter Heath of the Department of Logic, University of St Andrews, undertook this task and brought it to a satisfactory conclusion. To him also I would wish to express my thanks and congratulations.

Finally, I should like to compliment the publishers on their courage in giving my work a new lease of life in English. I trust that, in conjunction with Mr Hirtenstein's new case, it may serve to revive interest in these instances of persons born blind who later recover their sight.

Hamburg
November 1959

PREFACE

The task of supervising and observing the process of learning to see in persons born blind, who have been successfully operated on, is one which doctors and psychologists have always found particularly attractive and full of promise. But in many cases the execution of this task has proved less satisfactory than could have been wished, either for the welfare of the patient or in the interests of science; in cases, that is, where the psychological aspect of the matter has not been clearly recognized and has suffered, in consequence, from inadequate preparation. For in fact the operation, in the first instance, is only the necessary preliminary to a somewhat lengthy process of transformation which goes far beyond the physiological changes in the visual organs brought about by its performance. More especially for a patient advanced in years, it involves, not merely a gradual change-over in his perceptual life from a predominantly tactile to a predominantly visual mode of perception, but nothing less than a complete transformation of his whole mental and inner life, a gradual growing up into a new way of life.

There are a number of reports – to which relatively little attention has been paid, unfortunately – in which the process of learning to see has been described in successful cases, by very acute observers. They show that, to a psychologically trained observer, a congenitally blind person, once operated on, may on occasion be able to provide information, not otherwise obtainable, on a great variety of psychological and philosophical problems; and will do so the more, the better the operator and his patient are prepared in advance for the psychological task in hand.

Now, owing to the improvement in hygienic standards which has everywhere taken place, such operations, in which the patient is of the necessary age, and more especially the necessary intelligence, to be capable of training for psychological tests within the time available, are becoming increasingly rare. And besides, the need for such an operation often arises very suddenly for the ophthalmologist in question. I therefore consider it an essential duty that future cases of this sort should

be undertaken with the best possible preparation – especially as regards the questions to be asked and the test-objects to be employed – so that these rare opportunities may be exploited to the fullest possible extent. But for this purpose the study of previous cases is indispensable.

But since, however, many of the best reports are not easily accessible, and will not therefore be to hand during the short time available before the operation, one of my purposes in this book has been to give some account of the experiences of earlier observers, and thereby to throw light on the full meaning of the task of teaching congenitally blind patients to see after operation; and furthermore to revive the interest of the general public in a body of material which still remains wholly unexplored in detail.

My own treatment of the reports included here is concerned to analyse those passages which are of importance for the problem of the perception of space and form in the blind, before and after operation. The data relating to the pre-operative period have been analysed, firstly because they have not been dealt with before, and secondly because it is precisely from the contrast thereby disclosed between the pre- and post-operative modes of perception on the part of the patient, that it is first possible to understand correctly why the change-over to visual experience is bound to create such endless difficulties for the patient.

The tracing of the sequence of development in the patient's visual perception of form has been the most interesting task of the whole inquiry, because there we are dealing with a process whose individual phases cannot be observed in such clear-cut isolation in subjects with normal eyesight.

I could perhaps have abstained from giving any further account of how the perception of depth proper develops in the patient; but have done so none the less, because this question also has still not been satisfactorily answered, although it has hitherto formed the centre of interest in cases of this kind.

Out of regard for the length of the book I have, however, refrained from contrasting my findings with those arrived at by other authors along different lines, and have confined myself to giving a brief indication of these lines of inquiry. I have been confirmed in this policy by the consideration that these reports of how congenitally blind persons learn to see after operation provide such strange material – as regards both the *persons* and the *circumstances* of the experiment – that analysis of the data disclosed in them was bound to lead to conclusions requiring

special evaluation, and such that they cannot be set without further ado alongside findings arrived at by other means.

I should like at this point to express my special thanks to my revered teacher, Professor Wittmann, for the great interest and kindly encouragement he has shown towards my work.

Kiel THE AUTHOR

INTRODUCTION

Ever since Molyneux posed his famous question in 1690* and thereby directed the attention of the learned world to cases of persons born blind who have been operated on, these cases have attracted close interest in view of their recognized importance for the theory of our ideas of space. Moreover, the earliest English cases, operated on at the beginning of the eighteenth and nineteenth centuries, have become associated with various psychological theories which have remained more or less irreconcilably opposed to one another up to the present day: some seeking to trace our conception of space to a sort of inborn or inherited consciousness thereof; others holding that it is born anew in every instance from the experience of each separate individual; while a third school considers visual space in general to be a subjective fallacy and delusion.

If one then goes on to inquire as to the cases of operative blindness on which these theories are based, it is astonishing to discover that in general only a few examples in the literature are known about, namely these very same old English cases, which have continued to be cited for the last two hundred years, as though there were no more recent instances, considerably better documented and better reinforced by experiment. Even Helmholtz – though he mentions other examples – bases his empirical theory on the two cases of Cheselden and Wardrop, and in the last resort solely on a statement in Cheselden's report, which the latter wrote out from memory a considerable time after the operation. We shall have to examine this statement in more detail later on, when we shall see that it would probably never have occurred to Cheselden himself to draw such wide-ranging conclusions from the case in question. It seems strange, at all events, that in a matter of such importance a theory can be erected on so questionable a foundation; and it seems particularly odd that nobody should yet have taken the trouble to draw in full upon the very extensive material relating to operative blindness in order to settle the question as to the origins of our conception of space. And yet one might have expected that the

* *Cf.* Locke, J.: *Essay concerning Human Understanding*, Bk. II, Ch. ix, sec. 8.

later cases would throw more light on the matter, and that a consideration of the whole series would lead to a more coherent notion of visual space. For even today the treatment of the problem posed by Molyneux under such peculiar circumstances* has not yet been brought to a conclusion.

The external stimulus which led me to devote this work to a systematic study of all the available cases of this type, arose out of Wittmann's treatise on *Space, Time and Reality* (1), in which he points out the special importance of such cases for the problem of tactual space and himself reviews the subject from various angles. It must seem curious, indeed, that in this question of the spatiality of tactual impressions, which despite its great epistemological importance has led to controversies no less irreconcilable than those over visual space perception, the extensive material on operative blindness should not yet have been more thoroughly investigated. For it might well have been expected that such patients would yield more trustworthy information, since here there is less need to fear the difficulties of a common understanding of language than with congenitally blind persons who have not been operated upon; while conversely there is no influence from the visual recollections which readily blur the self-descriptions of persons blinded later in life, so that for the most part they can offer no reliable basis for investigation.†

Inevitably, therefore, there was a great deal to attract one in the task of making an accurate analysis of the data relating to tactile conditions in the congenitally blind, prior to operation, and then of enlisting the whole range of material on the subject in a further inquiry as to how the visual conception of space is developed once the operation has taken place. I was therefore only too glad to follow up Prof. Wittmann's suggestion by collecting the reports of operations on the congenitally blind and subjecting them to systematic review.

In order that in doing so I might have the collected material completely to hand and be independent of the brief lending-periods which foreign libraries allow, I made complete excerpts from the original texts of all the reports catalogued in the List of Cases, translated them,

* Naville (8) tells us: 'The problem was raised by Molyneux, a scholarly Irishman living at the end of the 17th century, who had made a particular study of mathematics and optics. Not long after their marriage his wife became blind. This fact, together with the special interests of the husband, probably led him to turn his attention to questions relating to blindness generally.'

† An honourable exception to this is Ahlmann's book *On the Analysis of Visual Modes of Thinking* (2), in which the author, many years after the onset of blindness, has set down his experiences of modes of thought and imagery in the blind in the form of psychological self-observations.

and then endeavoured to work over this material from a uniform point of view. Many of the source-references being extremely inaccurate, it proved impossible, in some cases, to obtain these reports. Thus Busoni's book *On the Unity of Music* (Berlin 1918) refers to a case, alleged to have been operated on in Detroit in 1915, which preoccupied him greatly for a considerable time; but with no further indication of source. In general there is reason to suppose that America still harbours a whole collection of such cases, which have not yet found a place in the literature. Unfortunately, too, in the penultimate American case, it has proved impossible to identify the author of the unusually sensitive psychological report on the eighteen-year-old American girl of Spanish origin. I therefore entitle it the 'Getaz case', from the name of the patient herself. Subsequent inquiries at the University of Lincoln (Nebraska) have elicited little beyond the fact that the case was neither treated nor examined there, though it was known of locally as a case that had actually occurred, so that the report is evidently not just a psychological exercise. The Kiel University Psychological Institute is continuing its efforts to obtain possession of the material still not available.

Already, since this book was completed, these efforts have led to the unearthing of Case No. 66. The reason it does not receive fuller treatment in the text is that it has not yet been found possible to supplement the newspaper report with authentic material from the University of Philadelphia.

From the clinical point of view, virtually all the cases involve operations for the removal of cataract. WARDROP II [16] and HIRSCHBERG II [25] were the only two to require the additional creation of an artificial pupil; in the most recent American case [66] the pupil was also missing, but the lens was normal; in case 65 there is said to have been a sudden and unexpected recovery of sight at the age of eighteen, without any operation. MESMER'S [9] and HEYFELDER'S [22] cases are said to have been amaurotic, the one due to paralysis of the optic nerves, the other to the effects of dazzling. Mesmer's patient (a woman) was enabled to see for several months by the use of magnetic treatment; Heyfelder employed galvanism in his case, apparently with lasting results. Not only Mesmer's patient, but RECORDON'S also, went blind again some time afterwards as a result of cribriform perforation of the membranes which had formed on both eyes in place of the lenses, their operative removal no longer proving sufficient to delay the onset of total blindness. The question as to how far the residual vision of cataract patients affects

their conception of space is dealt with in a special section (p. 71). Cases of the type which – although born blind – must thereafter be regarded for the purposes of our inquiry as already able to see before the operation, are distinguished in the List of Cases by enclosure of the serial number in round brackets, square brackets being reserved for those who did not go blind until after the age of three. As against this, the reports of DIDEROT [6] and VON UHTHOFF [54 and 55] are included in the list for control purposes, in order to determine if the tactual procedures characteristic of amaurotic blindness are different from those of cataract; the non-operative case of DUNAN [43] is intended to serve a similar purpose – a case recorded as blind from birth, though in actual fact blinded by accident when already in his sixth year, and properly speaking not qualified for inclusion, inasmuch as the experimental records show of this patient that even after thirty-two years his conception of space was still influenced by visual recollections.

The cases naturally differ greatly in quality, though almost all of them provide valuable evidence in one respect or another. In a series of 65 reports a certain uniformity might well have been expected. But this obtains only in so far as certain experiments, such as that of the sphere and cube initiated by Molyneux, are frequently repeated. It also emerges from the reports as a whole, that the process of learning to see in these cases is an enterprise fraught with innumerable difficulties, and that the common idea that the patient must necessarily be delighted with the gifts of light and colour bequeathed to him by the operation, is wholly remote from the facts. For the rest, however, there is no sort of conformity, either in respect of external circumstances or in regard to the physiological, sociological, intellectual or psychological peculiarities which have influenced the course of individual cases in many different ways and confronted the physician with one new problem after another. Such differences are also conditioned, moreover, by the varying ages of the patients (3–46), and by the differing interests of the reporters (as doctors, psychologists or teachers), so that sometimes it is the narrative, sometimes the method, on other occasions the scientific or ultimately the purely psychological interest which occupies the foreground in any given case.

This has been bound to make it all the easier, therefore, for mistaken conclusions to be drawn from observation of single cases; since it is always liable to present special features, the individual observer is never in a position to treat his own particular case as universally valid. Only a long run of such cases is capable of equalizing out what the

isolated instance leaves uncertain from a scientific point of view, and of enabling the broad general principles to be recognized.

For reasons already given, the reports themselves can only be compared with difficulty, and hence there did not seem much to be gained by assessing them one against the other, as it were; though in the interest of future cases the obvious defects inherent in many of the reports should not be passed over in silence. I have therefore confined myself to giving special attention to those authors in the case-list who by conducting systematic experiments either before or after the operation, and describing their outcome, have thereby endowed their reports with special importance for the purposes of our inquiry. Other reports (e.g. Nos. 1–3) are of such little consequence in this respect that they are only included in the list for the sake of completeness. They can be identified from the fact that little or no mention is made of them.

Lack of space has also prevented me from giving an account of the individual cases by way of introduction. The necessary information can perhaps best be gathered, in conjunction with the List of Cases, from the quotations, which provide the essential details in each case, so that the picture can be gradually filled in from these sources. The final column of the List of Cases also gives the pagings of references to the cases in question, in order to provide a further opportunity for obtaining a more or less complete picture of any given case.

Our analysis has been governed throughout by two major questions, as follows:

(1) Do the tactual impressions of the blind provide them with what can properly be described as an awareness of space in the same sense as the visual one?

This question has to do, not so much with any theoretical definition of the concept of 'space', as with the fact that – visually at least – 'space' is experienced. There may be dispute as to how the sighted person arrives at his spatial representations, how he develops his conception of shape, how he takes in an extensive area; what cannot be contested is that even though he has never been guided in any way in his mode of vision, he finds himself constantly located in an extensive spatial environment, that he invariably apprehends what he meets with as possessing shape, and above all that visual space exists for him, not as a piece of acquired knowledge or as the product of his own thought-processes, but as a purely sensuous ever-changing mode of experience, whereby he is continuously orientated in his spatial relationship to

whatever objects may be within his field of vision, and enabled to regulate his motor behaviour accordingly. In virtue of this permanent, wholly intrinsic, sensuous mode of experience, it is legitimate to speak of the sighted as possessing a deeply rooted 'spatial consciousness', and to ask whether the blind are similarly capable of developing such a 'spatial apprehension' (in relation to tactual objects) or acquiring such a 'spatial consciousness' (as applied in relation to their environment). (I deliberately avoid the term 'spatial representation' in connection with the blind, since it all too readily carries the suggestion of a visual memory-image.)

(2) How does spatial consciousness develop in congenitally blind persons after they have been operated on?

This second question also incorporates the specific problem raised by Berkeley which has hitherto been chiefly responsible for the scientific interest in cases of operative blindness, namely whether or not the patient's first visual impressions after the operation appear to be located in depth.

Before proceeding to analyse the cases it seems advisable to add some further preliminary observations:

(*a*) The blind man has acquired his vocabulary from his sighted teachers. The visual world being closed to him, he is compelled by his circumstances to invest many words with an altered meaning; as against this, our language is very poor in words drawn from the tactual sphere, so that the blind man finds no means of expressing many of the finer shades of his tactual experience within the vocabulary provided for him; he therefore has to rely, for better or worse, on words which in turn evoke impressions in the sighted that are by no means associated with these words in the blind man's experience and are not so intended when he uses them. All space-words, in particular, fall into this category. It is not always possible, however, to avoid the continued use of such spatial terms when referring to the experiences of persons born blind, even though it remains uncertain whether these words really have any spatial meaning for them. If I therefore qualify such spatial terms, so far as they relate to the mental life of the congenitally blind, by putting them in inverted commas, this is to be interpreted as a proviso, meaning roughly: 'so far as one can speak of this in relation to the congenitally blind', or: 'whatever a congenitally blind person may understand thereby'.

(*b*) The authors of the reports are for the most part unaware of the

problem of tactual space and thus have no definite attitude towards it. In so far as they have not undertaken systematic experiments, the details they record of the tactual experiences of their patients must therefore be taken to consist, rather, of inadvertent casual impressions; though they none the less derive a special value from the very fact of having arisen, entirely uninfluenced, out of pure unprejudiced observation. To estimate the value of such evidence we have felt obliged to weigh these individual statements in terms of their true meaning; not simply to accept them in every case at their face-value, but to interpret them, if necessary, in the light of the particular situation. Though there has also been a corresponding obligation to refrain from departing all too freely from the concrete sense of the words, thereby allowing interpretation to degenerate into an unwarranted process of 'deducing', 'attributing', etc., and manufacturing connections that are not really there. If I should nevertheless be accused of lapsing into introspective psychology at certain points in the analyses which follow, I can only assure the reader that such descriptions and explanations can either be supported from the text of the reports in question – but in such detail that space has prevented me from reproducing them *in extenso* – or else are confirmed by the behaviour of other patients in analogous circumstances.

(*c*) The arrangement of passages from the reports within each section generally adheres to their chronological order, except where the sequence of thought has made it expedient to depart from this. For since, in point of time, the reports tend to follow close upon one another in individual groups, such as the English cases at the beginning of the nineteenth century, for example, or the French ones in the latter half of it, there are many internal connections to be observed within the groups in question.

(*d*) The passages quoted frequently contain very interesting indications which would be relevant to the treatment of many other problems, and will certainly give the psychologist a great deal to think about. But the restrictions imposed have made it impossible to enter into any questions of this kind. For since the sources are in some cases difficult of access, I have felt it incumbent on me to present the passages bearing on the main topics of the inquiry with as little interruption as possible.

(*e*) The historical introduction to the problem of tactual space is intended to be purely introductory and makes no claim to completeness.

(*f*) References to the literature are given in round brackets ( ); allusions to case-histories of the blind patients in question are indicated by square brackets [ ].

PART I

Analysis of Pre-Operative Spatial Data

I

THE SIGNIFICANCE OF TACTUAL IMPRESSIONS

The so-called space of touch has become a problem only in modern times, since previously there had been no doubt on the matter. Descartes (10), in his *Dioptric*, invokes a hypothetical blind man for comparison, in order to assist his explanation of the visual process. He compares the colours seen by the sighted with the various tactual qualities which the blind man can feel when his reach is prolonged by means of a stick; and regards it as self-evident that in groping about in this way, and by the use of crossed staves, the blind man somehow acquires a mental picture of all angles and lengths; he thinks of touch as another form of sight.

Leibnitz (11) also puts the two senses of touch and sight on a par with one another, and supposes them both to create their knowledge of spatial forms and relations from a common source in pure understanding, without the need for experience (p. 129). In his view (p. 139) the geometry of the blind can be no different from that of a paralytic deprived of the sense of touch who becomes acquainted with the laws of geometry by purely visual methods.

> And these two geometries – that of the blind man and that of the paralytic – must meet and agree, and indeed return to the same ideas, although there are no common images.

Berkeley (12) is the first to make a perfectly sharp separation between the data of the two senses, though he also speaks of

> the extension and figure of a body, being let into the mind two ways, and that indifferently, either by sight or touch (§ lxviii).

Indeed, tactual objects actually have a more solid sort of reality, by comparison with the merely phenomenal optical appearances of things, which serve only to deceive us, by their changeable mode of appearance, as to their tactual size.

So too Hume (9):

> The idea of extension is entirely acquired from the senses of sight and feeling (§. 122).

DIDEROT also [6], in his report on the blind man of Puiseaux, makes it clear that he is convinced of the spatial character of this man's tactual impressions. He was, however, impressed at the time by Saunderson, the blind Cambridge mathematician, whose machine for calculating by touch he depicts, and whose achievements he cannot envisage except as based upon a consciousness of space.

E. Platner (13), who in 1785 spent three weeks investigating a case of congenital blindness with the express purpose of inquiring into the spatial consciousness of such persons, was the first to conclude that we merely allow ourselves to be deceived by the verbal habits of the blind and that in reality they have no awareness of space.

Hagen (14), writing in 1844, confirms this view. But even today, doubts about tactual space in the congenitally blind are in general regarded as a hardly excusable fallacy, which, as Fröbes (16) says of Platner and Hagen,

> can only be accounted for by the inadequacy of the factual information then available.

But in reality Platner (and Hagen) were the first to provide good grounds for liberating us from a belief which only continued to hold the field for so long because it was never seriously tested. Even so, the term 'feeling', for example, at that time still included all that we now keep strictly separate – active tactual impressions and passive sensations of touch, together with the data of muscular sensation and the sense of temperature.

Moreover, when psychology later took notice of this problem of the spatial character of tactual perceptions, it did so exclusively by adopting the methods of metrical science and with reference only to passive touch-sensations on the patient's own skin. But the question is in no way concerned with whether in passive sensation the blind man can locate the point of contact more or less accurately on his own body, or with the level of his threshold of discrimination in different parts of the body, but with whether by means of his active tactual impressions he can attain to any sort of conscious spatial conception of the shape of the object touched, and whether he is also able in some way to experience subjectively, as such, the objective space in which the sighted observer

actually sees him moving, whether he is in any way made aware of space itself as a reality.

It may be doubted, indeed, whether the blind man can correctly localize a passive touch-sensation without himself actively touching the place in question; and it may equally be disputed whether all these possible and often experienceable tactile impressions assist the blind man to take conscious cognizance of his own body, not only as a whole, but also, by virtue of the relation of its various parts to one another, as a figured object in space; but it is still more doubtful whether by active palpation of the touched object he can arrive in his consciousness at any sort of adequate representation of its shape – such as the spatial reality it possesses for the sighted person – and whether by his own movements in objective space he can attain to more than knowledge about this space.

This question, as to whether the active touch-procedures of the groping patient are subjectively spatial in character, has become a problem only in recent times, thanks to the well-known investigations of Heller (18), Steinberg (4), Katz (19) and others on the one hand, and the contrary findings of Wittmann (1), Ahlmann (2) and Gelb-Goldstein (3) on the other. It therefore receives little attention in the reports on patients under operation. Only a few authors – among them Franz, Nunneley, Fialla, von Hippel, Albertotti, Uhthoff and Ahlström – to some extent, no doubt (especially the first two), under the influence of Platner and Hagen, have taken the trouble to concern themselves in detail with the tactual experiences of their patients prior to the operation. The majority take the existence of tactual space for granted, while at the same time rejecting visual space as immediately given in optical perception; which thereby gives rise to the curious contradiction that the patient is supposed to acquire by learning, through sight, *after* the operation, something he is already supposed to possess by touch before it takes place.

Since, therefore, it is only in isolated instances that this question is posed as such by the reports, or attemptedly answered therein, it will be advisable for us to analyse under various heads the tactual activities of the patients as described in the reports, paying attention to the detailed circumstances and the explanations given by the author of the report in question. We shall also have to investigate whether and to what extent a spatial consciousness indubitably established, prior to operation, in any given patient, is already visual in origin. Moreover, the existence of this consciousness, in cases where it has been possible

to prove it, has never been thought to tell against the space of touch, but always against the original character of the space of sight. It is therefore important to analyse the spatial representations present in our patients prior to operation, in order to determine whether it is his visual impressions which first enable the patient to form a sort of spatial consciousness which he did not previously possess through touch alone; or whether it is a tactual space, given *a priori* or acquired through tactual experience, which is responsible for the fact that the patient has at once construed his modest store of visual impressions in spatial terms.

1. Apprehension of Spatial Depth

A. EVIDENCE IN THE SOURCES FOR A SPACE OF TOUCH

In entering upon an analysis of our material in regard to the 'space of touch', it seems appropriate to start from those passages which appear to give positive evidence for the conscious presence, in the minds of the congenitally blind, of a three-dimensional tactual space.

The first case we encounter is that of WARDROP I [15] (blind and deaf), where it is said that the boy's father often observed him

> to employ many hours in selecting from the channel of a river, which was near his father's house, small stones of a rounded shape, nearly of the same weight, and having smooth surfaces. These . . . he would arrange in a circular form on the bank of the river, and place himself in the centre of the circle.

Nothing is said as to the more exact nature of this procedure, as it presented itself to the watching eye of the father; but it may well be supposed that the boy squatted down directly on the river-bank, started first of all by collecting the stones at the water's edge, and then – simply by turning round on the spot – began to build his circle of stones on the other side of him, gradually rounding it out on either side and finally closing it opposite his starting-point. He therefore built the circle from the outside and then placed himself inside it, so that he seems to have become aware of it also from within.

Now how was this construction of a circle effected from the standpoint of the boy building it? At first it would appear as if he had really reproduced the shape of a circle somehow in his mind's eye and put the circle of stones together accordingly. Since, at the age of two, he had still had a certain degree of vision and according to his own clear recollection had also possessed certain technical tricks for producing light-stimuli (phosphene) or for increasing the amount of light (turning prisms or

pieces of glass against the sunlight), one might suppose it to be the visual memory-image of a circle that is in question here. The report on his visual experience shows, however, that in the last resort his vision consisted only in the qualitative enjoyment of such light-stimuli, which he indulged in as a game because it afforded him a certain sensory satisfaction, similar to that gained by tingling metal objects between his teeth; though without being able to make any use of these light-sensations for purposes of information. Still, he had got from this at least an inkling of what seeing means; he knew it to be an altogether special source of knowledge; for in making signs to communicate with those around him he always addressed himself to the eyes of his companions.

In other respects, however, his behaviour is so typically that of an impulsive and intelligent blind child – in groping along on all fours in unknown territory, for example, whereby for lack of auditory impressions he seems to have made use of his sense of smell – that there can really be no question of assuming his stone-circle to have been based on a visual memory-image. Nor, for that matter, is it difficult to trace the successful completion of this circle to his tactual experiences. Since he is described as an exceptionally lively lad with an insatiable curiosity and an energetic thirst for activity, we may take it that he probably became familiar with the tactual sequence 'circle from within' as a small child playing on the floor, in the course, maybe, of searching round about him for a fallen plaything by bringing his hands together in front and behind, noticing this twofold motion of both arms to be a peculiar one, and retaining it in his memory. At a later date – perhaps when exploring the waterbutt or the cart-wheel at his father's manse, both mentioned in the report – he may then have encountered this same tactual sequence in a different form, with both contacts of the hands transferred to the front.

This sequence, so typical in its construction, having been consciously apprehended on a number of occasions and reproduced in free motion with his own arms, could then be applied throughout to other instances as well – in this case to the stones on the river-bank: in forming this circular pattern the conscious activity employed will have consisted only in the slow, successive ordering of stones in a sequence furnishing the same muscular sensations to his continuously controlling arms as the already familiar tactual sequence 'circle from without'. It must be particularly noted in this connection that, being a deaf-mute, he would have had no knowledge of this expression as a description of the characteristic tactual experience in question, so that he really could not have

possessed anything other than this pure motor sequence, since the concept could not have been conveyed to him by a sighted person. The characteristic mark of this tactual sequence will have consisted, then, in both arms beginning close to the body in front and describing a movement away from it on either side, gradually projecting further and further as the trunk bent and ending by letting both hands come together again with the body at full stretch. After completing the task he will then have sat down so that he could feel out the whole ring of stones around him from front to rear and check the correctness of their arrangement. The correct ordering of the figure (circle from within) would then have been accomplished when, sitting still with arms extended and hands touching the ground around him, he could go round the stones without having to crook his arms in the process (bulge inwards) or lean his body over to one 'side' (bulge outwards). He could thus eliminate the bulges so discovered. The conditions to be satisfied by the completed figure would therefore consist solely in the continuous undeviating uniformity of his tactual progress round the ring of stones.

We see, therefore, that for his construction of this stone-circle it is quite unnecessary to suppose a conscious possession of the *spatial figure* of a 'circle'; he would also be able to construct a figure resulting objectively in a circle by means of the *touch-sequence* 'circle' and the characteristic kinaesthetic sensations accompanying it.

The conceptual clue to the work would then be, not the spatial idea of a circular figure, but a sort of schema containing not only the main features of the circle touch-sequence but also reference-points for the course of its completion. Such a schema would sum up, as it were, in a brief formula, those perceptual contents relating to a stretch of road, a surface or an object which had turned out to be particularly characteristic for purposes of distinction from other roadways, surfaces or objects, or had been found especially important for the orientation of the blind patient himself; it represents a quite plain and reasonable schematic summary, in the normal sense of the word, of important perceptual data, intended to serve the blind patient, on the one hand as a sort of *aide-mémoire*, and on the other as a guiding rule for his own practical procedure.

The schema aims at grasping what we call the structure of an object; even so, it is inadvisable to equate the 'schema' of the blind with 'structure'. For when as sighted persons we speak, for example, of the structure of a tree, we think too much in doing so of the spatial relationship of the parts to one another and to the whole; moreover, the posses-

sion of this spatial structure presupposes that we have previously experienced the tree as a whole. But this is precisely what the blind person has not acquired, and never can, even by use of the schema. Whereas the structure of an oak is different, for a sighted person, from that of a beech or a poplar, according to the difference in the total images of the trees in question, the blind man's schema is the same for all trees. Even when he is able, say, to finger all over a model tree and actually plant it in a tub, one still cannot say of him that he has thereby had a total experience of 'tree' as such. What he obtains from this is a series of qualitative impressions – extending from the gnarled texture of the roots to the twigs and leafage – and the temporal structure of change in these impressions, from root to trunk, branches, twigs and leaves. If he were to analyse these impressions more closely, he would be able to form a comparatively full schema of a 'tree', though it would continue to reproduce in compressed form the temporal structure of the perceptual process. In the ordinary way the schema 'tree' consists quite simply of 'trunk and branches', since the blind man cannot reach any further. Within this schema the typical blind man's notion of the trunk is fixed by the upward span of his arm, the gradual reaching up the trunk with his arms and the sudden checking of this (purely dynamic) upward movement by the lowest boughs of the tree. This experiential sequence is present to him in the schema 'tree = trunk and branches'.

We shall repeatedly come upon schema-formations of this type as characteristic traits in the blind before we again return to the subject in greater detail.

Now in the case of Wardrop I, the ring of stones is based on the schema 'stones round about' (in a dynamic sense); this schema embraces all the dynamic tactile experiences encountered by the boy in touching ring-shaped objects and later in ordering stones or other materials in a circular tactual sequence. Admittedly, the twelve-year-old deaf-mute could not formulate this schema in words; but his manner of procedure and its outcome show that his activities were mentally governed thereby.

In another passage Wardrop writes, of the same case:

> He appeared well acquainted with the furniture of the room, having lived in it several days previous to the operation. . . . Indeed before the operation he always walked with much freedom, and . . . even on a very rugged and unequal road he did not stumble, or suffer in the least from jolting.

He will have been accustomed to rugged roads from his home in

Scotland; and the need to feel systematically all round a room in which some time has to be spent is common to all blind people. But this case is particularly interesting because it shows what a range of knowledge is obtainable even by a person who (being blind and deaf-mute) is almost exclusively dependent on his sense of touch, if only he is in a position to unify all his tactual impressions into a closed system. The fact that he was so freely able to indulge his tactual curiosity on expeditions which took him several hundred yards from his home in all directions, was due, however, to the comforting knowledge that he was always furnished with a 'sighted' companion, whom he was accustomed to wait for whenever there seemed to be some serious obstacle in his way.

The other passages in this report which might warrant the assumption of a spatial consciousness, relate to a period after the first operation, which only restored his sight for the space of a few weeks.

The space of touch is also positively upheld by RAEHLMANN [46] in the introduction to his report, where he credits his patient with a 'system of spatial intuitions developed in him by the remaining senses'. But he fails to disclose the grounds on which he bases this conviction. In his view all congenitally blind persons have

> a representation of the external world and of the spatial extension of things therein. . . .

At the beginning he also expresses the hope of being able to question his patient with some prospect of success as to

> whether and in what respects the space he sees differs from that which he felt by touch while still blind.

He does not seem to have arrived at any satisfactory result, however, since he gives no account of the execution of this plan. At the end of his report he still continues to believe in a space of touch, at least within immediate arms' reach; he says, indeed:

> Thus our patient certainly did not possess innate spatial representations in the sense in which they are provided for us by the sense of sight,

but then goes on:

> although he had, and must have had, a representation of the external world and its spatial dimensions by means of his other senses. . . .

Further on we are again told:

> If he had not been able, by means of feeling, to compare his visual impressions, which opened a new sensory world to him, with the old

> world already known to him, he would not have straightway taken the space seen to be identical with that known by touch.

How this supposed space of touch is actually constituted emerges in the course of an extract from the visual tests:

> On being asked whether he recognizes anything in the room he turns his head and eyes to the left, points to the white-tiled stove and the door (both about 6 feet away) and designates each of them correctly. The patient has frequently encountered both objects on getting out of bed, and from these tactual experiments has learnt their position in relation to his bed.

Thus the procedure here is precisely analogous to what we have just noted (p. 33) in Wardrop I:

> He appeared well acquainted with the furniture of the room, having lived in it several days previous to the operation.

Here too it is enough to suppose that we are again confronted with typical schema-formations. Here too, where living-rooms are concerned, there is a common endeavour on the part of all blind patients to stabilize the environment in which they are situated – in particular the room where they have to live for some time – by means of certain fixed coordinates and to determine these latter exactly in a tactual sense. The patient in Raehlmann I had likewise established certain landmarks in this fashion, proceeding outwards from his bed as the central point. In the experiment described by R. he now turns his head to the extent known to be required and governed by the muscular tension necessary for the purpose, and thereby realizes that the objects now located 'in front of' him must be the stove and the door.

HIRSCHBERG [24] also postulates a certain consciousness of space in his seven-year-old patient; but of this boy it is doubtful how far he was already assisted by visual impressions. This case will therefore be dealt with in detail at a later stage (p. 77).

FRANCKE'S case [50] undoubtedly possessed some consciousness of space already, before the operation. But there is equally little doubt that this consciousness was also of prior visual origin; for he knew the main colours and could make approximately correct estimates of distances within his reach by optical means. Even before the operation a remarkable change had occurred in him: touch was still indeed his main sense, since his powers of vision did not extend to the apprehension of visual shape. But he had systematically measured off all felt spatial dimensions with a tactile tape-measure and compared them against the muscular sensations in his measuring hand; thus he had deliberately

practised estimating distances with his hand and seems also (though this indeed is not expressly noted) to have tested the remoteness of his visual impressions with the same instrument. The visual space that he had acquired in this manner does not seem, however, to have had any prior basis in a tactile consciousness of space. On the contrary, he seems first of all to have simply taken the various sensations of stretching felt when his hand was spread out in varying degrees and correlated them with the distances marked on the tape-measure in a purely tactile fashion, without thereby entertaining any spatial awareness of the distance actually intervening between his finger-tips.

MINER [59] has made comparative studies of the reproduction of horizontal lines from memory by sight and touch, which are said to afford 'some evidence as to the relative value of visual and tactual space'; but he does not record his values either for the differences or for the time-intervals separating the original tactual manipulations carried out on the object and the tactual estimates later reproduced from memory without the object. Nor can such experiments throw any light on the problem of spatial representation, because tactual reproductions of this sort amount to a reproduction of the stretching sensations felt in the measuring hand during the original tactual manipulation, and therefore to purely qualitative muscular sensations in the hand.

Lastly, it is said in SCHNABEL II [34]:

> If one led the child successively from a particular place to two different parts of the room, she was perfectly capable of telling which was nearer and which farther from the starting-point.

This girl-patient claimed, indeed, to have no sort of recollection of how objects looked, although she only went blind gradually from her fifth year onwards and when operated on at thirteen still had some residue of vision left; it will appear on a later occasion, however, that she still had a visual awareness of space. Even so, the feat as such would offer no immediate proof that she had developed an awareness of space from the movements of her own body, since in other congenitally blind patients a similar assessment of distance traversed is based on counting the steps taken, or on an estimate of time.

B. EVIDENCE IN THE SOURCES AGAINST A SPACE OF TOUCH

The cases which outwardly, from the nature of the tactual activities depicted therein, appear to tell strongly in favour of a space of touch, have thus already been disposed of. We have seen that these examples

scarcely provide strict evidence of a tactile space. We now turn to those cases in which either the authors themselves reject a space of touch, or in which the facts reported reveal such a space to be an unwarranted fiction.

The case of WARE I [11] has been rejected by all later observers as one of those cases in which the patient was able to apprehend visual space immediately after the operation only because he could already see beforehand to a sufficient extent. Ware himself disputes this, indeed, but he had done nothing to test the visual capacity of his patient before the operation. He assumes, rather, that the mere recognition of colours must already necessitate the creation of a visual consciousness of space, because even within so restricted a field as that of colour-recognition the approach and regression of these colours will be bound up with phenomena such as to yield a representation of the spatial. We shall see later, from other cases, that one cannot generalize in this fashion. It would appear, however, that Ware rejects the assumption of a tactual consciousness of space, when he says:

> that the ideas derived from feeling can have no power to direct the judgement, with respect either to the distance or form of visible objects.

NUNNELEY'S [21] patient was able to find his way all about the very large village he lived in; and yet N. has to admit: 'Of distance he had not the least conception.' Only those things with which he had actually been in contact had ever been real to him; he had never acquired the notion of spatial distance and hence even his visual investigations were conducted under the impression that everything he perceived was in immediate contact with his body.

DUFOUR [26] sums up this situation as follows:

> The patients have difficulty in conceiving that our senses carry so far and in a sense can also perceive so far; nor can they imagine a great distance in any other way save in terms of the time one has to spend walking in order to get there.

And after his patient has already been seeing for several days and been very laboriously instructed, Dufour again observes:

> He sees contours and colours; but when I talk to him about a very long distance, it does not seem as though he can imagine any such thing.

Here too, therefore, distance, for the patient, had been an affair not of space but of time; and even this conception of distance had not been acquired by the blind man on his own account, but rather from the need

to fill out an expression so frequently used by the sighted with some sort of content intelligible to himself.

In ALBERTOTTI [39] we find a complete lack of even the most primitive spatial concepts, his patient being unable, even by touch, to discover the simplest and crudest differences among objects presented to him. 'He had no idea of depth, confusing it with roundness.'

The following observation is nevertheless especially characteristic:

> He has an accurate idea of the location of objects in space in relation to his own body, so long as it is possible for him to touch them directly with his hand, without having to turn round.

In effect, this passage shows exceptionally clearly that the blind man's seeming consciousness of space is no more than a knowledge of the possibility of being able to lay his hand on an object by executing a specific movement of the arm, characterized by a particular muscular sensation. It is quite unnecessary to suppose that the vectors of these grasping movements extend into depth for the blind man, in the spatial sense of the sighted person, or are distinguished from one another by their relationship to the spatial field; there are better grounds, at all events, for envisaging them as *dynamic* lines-of-action of some sort, proceeding from the agent's own body, which acquire their possibilities of distinction from the accompanying sensations of tension felt in the arm-muscles, and in the varying expansion or contraction of the thorax, as Ahlmann (2) has in fact testified in regard to his own case. In accordance with the normal range of his arm-movements, the blind man therefore orientates himself only in relation to the objects he can lay hold on within the sphere of muscular action; and if there is justification for the assumption that even this sphere has nothing consciously spatial about it, so much the more are we entitled to suppose that there is really nothing existent for him in rear of it. What he possesses are certain lines-of-action extending objectively 'in front' of him, which have this special meaning for the blind man because their particular dynamic character is related to the dynamic sensations occurring in progressive movement. This comes to light in the test carried out by Albertotti, prior to operation, with the chandelier; though it is somewhat vitiated inasmuch as some degree of vision was already present: the patient determines the direction from the point where the light is strongest, by turning his head towards both extremities; having found the direction, he stations his body in the middle, stretches his arm forwards, keeps his whole body in this attitude as rigidly as possible so as to avoid any deviant motion

of his body, and controls each pair of steps by eye according to the same method, namely whether the source of the light is still in his line of march. Albertotti says of this experiment:

> He therefore possesses in some degree the idea of the direction of the light and also retains it up to a point in his memory, but does not know how to guide himself while walking, inasmuch as he has not formed any idea of the position of the light *a priori*, from indirect indications.

The young man behaves in this experiment exactly like a blind man and makes use of his optical impressions only as indirect qualitative indications of this kind. His goal-directed motion as such is carried out without these visual aids; and hence it can be seen that he is not really pursuing a spatial direction, but is trying to avoid departing, by a deviant motion of his body, from the purely forward movement whose accompanying symptoms have special qualitative features for him, and which he has directed at the outset, by indirect means, at an optical goal.

In order to understand how blind people 'walk', it is sufficient to assume – what is completely confirmed by Ahlmann (2) in any case – that ordinary straightforward movement on their part is a sort of dynamic state of equilibrium, in which both sides of the body are equally in tension, but in which the whole bodily tone is displaced 'forwards'. The legs, indeed, are in rhythmic motion, but even under this tension the upper part of the body seems to them to remain as it were stationary and persistent. It is unnecessary to assume that they have any adequate consciousness of the objective change of location they effect by means of this walking motion. What a sighted person regards as his line of advance is for them a knowledge that after a certain number of steps they will reach the object sought, provided they continue in this characteristic bodily posture. To this we may add what Helen Keller (15) says at one point, when asked what a straight line means to her:

> When I have something to do that must not be set aside, I feel as if I were going forward in a straight line bound to arrive somewhere, or go on forever without swerving to the right or to the left.

These words give striking expression to the fact that the 'forward march' of the blind is characterized, not by the notion of a straight line in space, but by a particular psycho-physically goal-directed posture which signifies a straight path to them. From these words of Helen Keller's the *schematic* character of the 'straight line' also emerges with great clarity.

The fact that a movement executed by a blind person, or movements outside him that he follows by touch, are given for him in the first place,

not as an imagined change of position in space, but as a change in the relative muscular tensions of his own body, is particularly clearly shown in the case treated by MOREAU and LEPRINCE [63]. For this eight-year old boy was one of the rare cases in which the purely qualitative impressions of the various senses had remained uncontaminated, since neither by the instruction of others nor by dint of his own thought-processes had he managed to extract concepts from his sense-experiences. Objectively speaking, he had made plenty of movements, but still did not possess the concept of 'movement' in the sense of a change of location. The fact that in his first attempts to see a movement he was unable to follow the hand that moved, but continually took this movement simply as an interlude of light and darkness, proves nothing by itself, since it might equally well have been due to a somatic inability to follow in this fashion. The sequel shows, however, that he did not couple the word 'movement' with any change of position: Moreau says in his report:

> When he was presented with a hand in motion and had continually repeated his 'I don't know', the test was taken a step further by saying to him 'Don't you see that it's moving?' Again the child's answer was 'I don't know', in a voice of questioning ignorance. It could be seen how the child was struggling to grasp the meaning of this phrase in relation to the gesture. He was clearly trying to grasp it, but without success. His eye failed to follow the long swinging motions of the hand. . . .

Leprince says in this connection:

> . . . although, when one passed a hand or an object in front of his eyes and said to him 'look, it's moving', he did his best to understand, he still did not succeed in grasping the meaning of the words. He took it purely as an interlude of light and darkness, without there being any awareness in his mind of a change of position. He gained this knowledge only by means of a tactual image.

Not until he was allowed to touch the moving hand while it was beginning to stir did he cry out joyfully 'in a voice of triumph: "It's moving" '.

Thus the failure here to recognize an optically given movement is due to an inability to follow, not on somatic, but on psychological grounds. It is not as if the child, having learnt that what he sees represents an object in motion, says to himself, as it were: the thing is now changing its position, I ought to be following it with my eyes, but I can't do so; the fact is that it simply does not occur to him that 'movement' involves a change of direction of the perceiving organ; and this because even

tactual movement has never been given to him in terms of a change of direction in space. Hence it was not even the 'tactual image' of movement (as Leprince puts it) which enabled him to grasp a movement visually perceived, but rather the familiar sequence of changing tensions thereby occasioned in his arm-muscles, which was produced in him by touching the moving hand. The felt changes occurring in the course of tactual movement were referred, not to a consciously apprehended space outside his own body but to that body itself; though here again, not in a spatial sense, as a spatial change in the relative position of different parts of the body, but as a change in the arrangement of the limbs in relation to the body, apprehended through the muscular sense. At the end of his account Leprince summarizes his impressions of the case as follows:

> He makes use of his new sensory equipment only for the purpose of reinforcing the other senses, by whose aid he had hitherto been able to live, but which had been unable to furnish him with the exclusively visual sensations of space, motion, colour and shape.

C. STATEMENTS OF THE PATIENTS

We also have *testimonies of such congenitally blind persons themselves, after they have regained their sight*, which point to the fact that when blind they possessed no consciousness of space. One such testimony is to be found, for example, in the statement of CHESELDEN'S [5] patient, after operation, that:

> the room he was in . . . he knew to be but part of the house, yet he could not conceive that the whole house could look bigger.

Not only the situation as such, but also the very words themselves make it perfectly clear that all the 'spatial concepts' he had thought himself to possess before the operation had nothing in any way representational about them, but were merely a pure knowledge of fact, which he could only have acquired from private reflection, coupled with instruction to that effect from other people.

This is even more clearly stated in the American GETAZ case [65]:

> Those who are blind from birth, according to [the eighteen-year-old] Joan's experience, have no real conception of height or distance. A house that is a mile away is thought of as nearby, but requiring the taking of a lot of steps. . . . A skyscraper is not thought of as towering into the heavens, but as indefinitely higher than a blind man can reach. The elevator that whizzes him up and down gives no more sense of vertical distance than does the train of horizontal.

Here too it is again apparent from the patient's own statement that motion itself is not presented to the blind man's consciousness as change of position, but is transformed by him into the time wherein he experiences those typical concomitant phenomena which affect his body while he is carried along. The indirect signs that he is at present 'moving' in a lift or a car are the accompanying noises of the engine, the wind rushing by, the bodily vibration, sensations of tension in the overcoming of his own inertial resistance, displacements of blood in the body, etc. All this, however, is felt within his own body and referred thereto. What is presented to consciousness is the peculiar condition occasioned in the body by the motion known to be occurring. 'She had no real sensation of covering distance.'

2. Apprehension of Tactual Objects

The problem of tactual space in the blind can also be raised, and has been hotly contested, as a question of whether, by simultaneous or successive touch, the blind person can obtain a spatial representation of the objects touched. The essential issue here is not merely whether the congenitally blind patient feels the object as a source of resistance, but whether it is presented to his consciousness as a body occupying space, and whether in this spatial form it possesses any kind of picturable *gestalt*. Here too we must not immediately presume such a spatial consciousness, or tactual *gestalt*, to be given whenever the patient describes the form of an object 'correctly', i.e. in such a way that, for sighted persons like ourselves, his words yield a description answering to our visual impression of the object. We must endeavour, rather, to discover whether here too the patient is not employing words to which, in virtue of the peculiarity of his tactual experience, he attaches a meaning quite different from that of the sighted, who have furnished him with this vocabulary without having previously projected themselves into his peculiar conditions of perception. Even among sighted persons the same words do not always have the same meaning, and this is all the more true of verbal intercourse between the sighted and the blind. Helen Keller (15) says:

> In large measure we travel the same highways, read the same books, speak the same language, yet our experiences are different.

Hence it is that the only possibility we have of penetrating the secrets of the tactual world of the blind consists in questioning those people who have successively had experience of both the blind and the sighted

man's world; or in carefully observing how, after operation, the blind person only gradually masters the new sense that has been opened to him, how he has to cast off certain old ways of thinking derived from his earlier condition of perception, since they cannot be brought into line with the entirely novel visual impressions he now has, whereas others can be taken over unchanged. And from all the reports on such cases it may be seen that in this connection it is the 'spatial concepts' that he has fashioned for himself which undergo the greatest transformation, and the most difficult to achieve.

A. BY SIMULTANEOUS TOUCH

Concerning simultaneous touch we do not in fact find any generally applicable evidence. But a passage from FRANZ [17] is worth noting:

> In feeling an object and bringing it in contact with the eyelids and the cheek, . . . an idea of the object was produced, which was judged of and corrected according to the experience he had gained by constant practice.

However, the patient plainly did not execute this movement with a view to grasping the spatial form of the object by tactual enclosure between hand, cheek and eyelid, but supposed that he would obtain visual sensations on bringing the object *into contact* with his eye. His other manipulations show likewise that he was concerned not with spatiality, but with the knowledge and enjoyment of the finest textural nuances in objects; he was a sort of tactual aesthete. The tactual impressions on the soft skin of the eyelids, cheek and lips were more fully differentiated in quality, and the tactual surfaces themselves more sensitive to temperature, than on the horny finger-tips.

> The sensation produced by silk stuffs was most pleasing to him.

We may also recall the passage already cited (p. 30) from WARDROP [15], whose patient is said to have employed many hours

> in selecting from the channel of a river . . . small stones of a rounded shape, nearly the same weight, and having smooth surfaces.

Nothing is said, in fact, as to the absolute size of the stones; but one must suppose them to have been of a moderately handy size, large enough to be capable of arrangement in a circle within a reasonable time, but yet small enough to be fetched from the river in considerable numbers. Here too, therefore, the quantitative element consists, for the boy, not in the shape and size of the stones, but in their handiness and weight, and thus again relates to a sort of inner perception of his

muscular sense. The uniformity which struck the watching father as a uniform roundness in the outer shape, lay, no doubt, for the boy, not in a spatially imagined shape, but – the weight apart – in a uniform 'fullness' of his encompassing hand, and in the smooth polish, without sharp or broken edges; smoothness is, indeed, felt to be 'beautiful' by blind people in general. What he felt and apprehended in his passively 'en-' compassing hand were the qualitative impressions of smooth and rough-edged, but not a simultaneous synthetic impression of a round or cornered shape.

B. BY SUCCESSIVE TOUCH

There are many examples in our sources of the *successive touching* of larger objects which cannot be encompassed all at one time.

In the case of WARDROP I [15], Dr Gordon gives the following account of the procedure of the blind deaf-mute, James Mitchell:

> When [any object that is new to him] is put into his hand, he runs it over with the points of his fingers; then applies it to his mouth, and insinuates his tongue into all its inequalities, thus using it as an organ of Touch as well as Taste; and lastly, if it is a body that admits of it, he rattles it between his teeth. All this is done with singular rapidity. In fact, he loses but little time, in discovering, by the actual use of his organs of touch, taste and smell, those qualities of bodies which we are content to infer from their visible appearance alone.

Here one might at first get the impression that the object of the boy's eager exploration of all surfaces, edges, grooves and other irregularities was to combine all these details into an overall tactual image; were it not that the author himself draws the conclusion, from his own observations, that the boy was thereby enabled to pin down the maximum number and variety of qualitative features in the individual object and incorporate them into his store of knowledge; obviously with a view to obtaining a larger number of possibilities of identification for future occasions, and so being able to take note of the object by means of the senses still remaining to him.

This systematic combined employment of all the senses upon one and the same object often recurs in the reports; and may well be taken merely as an indication that in such collecting activity the blind man is aiming, not so much at obtaining a total impression of the spatial physical shape, as at amassing qualitative data which shall aid him in the process of identification.

Apart from the effort to identify, the interests of this blind deaf-

mute were centred on what could be done with all these various objects, and how far they could satisfy his play-instinct. His sister says of him:

> He knows the use of all common things, and is pleased when the use of anything with which he is not acquainted is communicated to him.

Thus it is observed for example, in another passage, with regard to a visitor's carriage, that he

> examined the whole of it with much anxiety and tried innumerable times the elasticity of the springs.

From this it may be inferred that in dealing with all such objects he was not attempting to obtain a total impression of the given tactual object, but was concerned with any sort of details so far as they gave him an opportunity of busying himself with it. It is not possible to tell from a single instance whether he had the chance of forming such a total impression, albeit not a spatial one, but this may well be supposed, in view of the extensive system of environmental relationships that he had established, of which more will be said later.

As against this, RAEHLMANN II [47] provides us with the case of an intelligent girl, in whom the succession of tactual impressions had not enabled her to arrive at a complete spatial image:

> She explained that on previous occasions she had handled dogs, and had also seen the head, ears and legs; but she had no proper idea of how the parts she had seen were conjoined together; only now did she see for the first time how the legs were separated from one another, how far away they were from the head, etc.

This statement is the more notable in that this girl is among those cases who had already possessed a certain degree of vision prior to the operation; and she had quite deliberately tried to use it in order to arrive thereby at a total physical picture of a 'dog'. But neither visually nor tactually could she succeed in forming this idea. The outcome of successive touching in this case was a number of part-sequences of tactual impressions obtained from the individual limbs, and all known to belong to the one total object, though they could not be pictured as a whole. She evidently did not have at her disposal the methods which are said to have enabled other congenitally blind patients to combine the separate parts touched and measured off by them into a whole. But a whole thus presented by technical means would also not have become known to her as a spatial and physical whole; she would have been aware only of the mutual interrelations of the various limbs to one another

and to the body as she felt it; she would merely have acquired the schema 'dog'.

VURPAS-EGGLI [53] write of their second case (aged $4\frac{1}{2}$):

> When he has taken hold of an object he feels it all over and examines all its surfaces and finally conveys it to his mouth and runs over it with his tongue.

This child, like the other five-year-old they refer to, also continued in this habit after being operated on, and could not be induced to make use of his powers of vision. Nor were the authors themselves able to come to any clear conclusion as to how they should interpret the behaviour of these children:

> As regards the testing of certain conclusions arrived at by earlier investigators, to which we particularly wished to direct our inquiries, for instance, as to the concept of space . . . the immediate, or non-immediate perception of the shape of objects, reliefs, etc., the experiments we were able to make in this connection have not given us the complete satisfaction for which we hoped; and this was due, of course, to the youth of the two children and the very low level of their knowledge.

Clearer and more conclusive indications as to how we should interpret this mode of touching are provided by NUNNELEY'S case [21]. Here, as in WARDROP I, we might at first be inclined to endow the patient's successive touching, using one or both hands, with a certain spatial character:

> I presented to him in succession a great number of different objects, each one of which he took into both hands, felt it most carefully over with both, then with equal minuteness with one, turning the object over and over again, in every direction; the tongue was next applied to it; and lastly, he applied it so near to the eye as to touch the eyelids, when he pronounced his opinion upon it, and generally with correctness, as to the nature and form of the object, when these were distinct.

But when Nunneley then goes on to enumerate the objects examined by his patient (books, stones, small boxes and variously shaped pieces of wood and bone), it can be seen that the interest of this young man was centred merely upon identification, which he endeavoured to accomplish by means of qualitative analysis. For if the shapes of these objects had in any way evoked a specifically figured idea in him, he would immediately have distinguished these very objects, so markedly different in shape, without any trouble. But in fact his impressions of

contour were so indefinite and so little capable of representation that he very easily became uncertain:

> In an object where the angles were not very distinct, he made constant mistakes in the shape, first saying that it was square, then that it was round.

What he is aware of is the tactual impression of a sharp edge, or the lack of such. The feel of this edge is equivalent, for him, to 'square'; in the absence of this impression, he takes the object to be 'round'. It is only the sighted persons around him who continually talk to him of the shape of objects; but the latter is not given to his own mind, he merely notes the tactual impressions which enable him to determine what it is that sighted people call the shape of a thing. On his part it is a case of having to exercise his mind in a sphere which, on the strength of his purely tactual experiences, is alien to him.

For a completely crass instance of this, we may again refer to ALBERTOTTI'S case [39]:

> He has absolutely no idea of what we understand by the shape of an object.—In like fashion, his judgements as to the nature of objects were made essentially without any regard for the successive impressions that he might have derived from feeling them over in any direction with his hand.

It may be said that, given the situation depicted in the second statement, that in the first was only to be expected. It might also be said, however, that he had omitted to feel with his hands because, for lack of any systematic guidance in the use of these tactual impressions, he did not know what to make of the two-handed touch-sequences thus obtained. And indeed, when touching with both hands he had no idea at all of the position of his hands in space or in relation to one another:

> When asked to use both hands, he was unable to form an idea of the distance between them, and was therefore misled in the estimates he sought to make by use of this criterion.

But we cannot attribute all these deficiencies to his own indolence; this is evidenced by the fact that, unlike most of the other cases, he measured off objects, using the span of his fingers as a unit, in order to determine their absolute or relative size. This is particularly noteworthy, since it also offers further proof that such measuring-off with the aid of auxiliary units does not lead to a spatial apprehension of the bodies so measured, but to purely mathematical number-relations. When Albertotti's patient was called upon to compare two edges of different

lengths, and found one of them to be 2 spans long, for example, and the other 3, the second was 'longer', not because he had in fact consciously perceived it to be so in a spatial sense, but firstly because it had taken a longer time to measure, and secondly because 3 is a larger number than 2. These purely numerical operations are within the capacity of the blind man because they do not necessarily have to be grasped intuitively; they satisfy him as purely conceptual results of the ordering-processes of his own thought.

From a purely intellectual point of view he would also have been capable, therefore, of using both hands for successive touching; and did in fact learn, under guidance, to do so. That he had not done this, and had considerable difficulty in learning it, merely shows once more that the tactual thinking of the blind is from the outset non-spatial. But if so, one cannot expect what is artificially conveyed to them from outside, in the course of training, to be a true consciousness of space. It cannot be more than a sort of fancied 'space', a learnt knowledge of the relationships in which visual space is given to the sighted. Albertotti continues:

> Since he was therefore unaccustomed to making use of touch by following the contours of objects with his fingers, he was also unable, in consequence, by relying on himself, to tell the difference between a rectangular and a round piece of card, each about a square decimetre in extent; he took a die and a wooden ball, each of 1 cubic decimetre in volume, to be of the same size and thickness; both these objects seemed alike to him, and differed from the pieces of card in that they were 'a tremendous lot bigger'; the notion of weight obviously entered in here.

There can be no doubt, therefore, that his mere natural tactual impressions of bodies felt in both hands, without the use of mechanical aids (measuring techniques) or auxiliary ideas of time, for example, were non-spatial; nor, from his kinaesthetic sensations on touching these bodies, did he have any spatial sense of the varying positions of his own limbs in relation to the bodies, or to one another. (Even as sighted persons we very quickly lose this sense in a dark room, though we continually make use of visual imagery to help us in this.) He therefore had no real idea of the size of objects clasped between his hands.

We can also learn from Albertotti how it is that the patient acquires these 'spatial concepts', i.e. how he is able to come to the false use of 'spatial' terms:

> When I took his hand and guided his fingers over the contours of the little cardboard discs with which he was already familiar, he came out

with the remark that 'one of the discs had points and the other did not'. From then on he was no longer content merely to touch the objects stealthily and then at once to withdraw his hand; he felt over them, and the notion of points became for him synonymous with angularity, and their absence with roundness; thus a spoon was round and a fork angular.

The tactual impressions he actually had when traversing the contours are here exhibited in a perfectly definite manner: 'Points' is the name given to the tactual impression of a corner, which arises when the pressure on his finger is no longer distributed – as it is when running along an edge – over a fair number of Meissner's corpuscles, but acts more strongly, accompanied by a pricking sensation, at only *one* point on his finger-tip. Again, the corner is marked for him by the fact that the uniform monotonous sequence is suddenly interrupted, so that his touching finger runs, as it were, into the void; whereupon the finger must seek a new dynamic line of advance for its pressure, which is given by another edge. The whole is a purely qualitative tactual experience, but the corner represents a quite distinct turning-point within the tactual sequence; and such a moment of discontinuity is also much desired by the patient – he is glad that there is something more to be said about the touched object, and something which may also be of practical value to him. But when he now employs the terms appropriate to our visual space, these expressions have a totally different meaning for him from those of our ordinary usage. What are features of shape to us are for him wholly unspatial, purely tactile distinctions of sensation or dynamic movement; they are distinctions in the constancy of sequence and ordering of impressions. Whether he says 'point' and 'not-point', or 'angular' and 'round', makes no sort of difference to him, both being mere vocables for the same tactile sense-impressions; the sensations themselves are not rendered spatial thereby.

We encounter the same thing equally clearly in VON HIPPEL'S case [23]. As the result of post-operative tactual tests on his four-year-old girl patient, he himself concludes,

that notions of bodily form acquired purely through feeling were only developed in the child to a relatively slight degree.

But if we analyse her behaviour during these experiments more closely, we shall rather come to the conclusion that she had no 'notions of bodily form' whatsoever. Thus the word 'ball' meant to her, not the abstract idea of spherical form, but the qualitative impression experienced on touching a particular wooden sphere; the latter being specified by its

particular surface-structure (smooth, hard, etc.), by an acoustical impression derived from touching it (wooden), and by the ability to clasp it all round, without encountering any special points of tactual interest – this in consequence of its objective bodily form. But this latter sensation is associated, not with the spatial form of the sphere, but with a knowledge of what can be done with it, namely that given an object which feels like this, she can set it 'rolling'. Thus the glass ball given to her is regarded, not as a 'ball' (the feel of its texture being different), but as a completely new object. In her conception of 'ball', both sensations, that of the surface-structure and that of the absence of corners, were inseparably connected. At this point, however, the one impression known to her – that of what we should describe as the bodily form – detached itself from the textural impression that was strange to her, and caused her to recollect that objects without corners can be rolled; and this led her to surmise that perhaps this object can also be rolled; though here the child associates with the idea of 'rolling', not the sort of rolling movement that we can follow with our eyes, but the particular characteristic auditory impression involved – uniform, monotonous, gradually becoming fainter and eventually stopping all at once.

This is even more clearly evident in the trial with a cube. A 'cube', for her, represents, not so much its particular *form*, with equal sides running parallel to one another, but rather the sensation given by the edges. If the edges are rounded off, then – as in Albertotti's case – she no longer treats it as a 'cube'. The concept of 'cube' thus attaches, for her, not to the spatial object, but to the tactual impression of the edges.

When FRANCKE [50], referring to von Hippel, reports, on the contrary, of his twenty-six-year-old patient:

> a sphere, a cube, etc., were invariably recognized by touch, regardless of the materials of which they were composed, or of whether the cube had sharp or rounded edges,

we must attribute this to the fact that, as we shall see in more detail later, his patient already possessed a visual awareness of space and, throughout all the systematic tests employed, knew how to make use of his small powers of vision in order to grasp the significance of his tactual impressions.

How little such tactual sequences have to do with the apprehension of space is shown by this child of VON HIPPEL'S [23] in her comparative estimates of the length and thickness of two objects.

> Thus she declared of two keys, for example, one of 12 cm. in length and the other of 7 cm., that the latter was the larger; a ball of 5·5 cm. diameter was said to be smaller than a cube having an edge of 2·5 cm. When I put into her hand a round wooden stick, 43 cm. long and 1 cm. thick, together with a lead-pencil, she took the stick to be longer, but the pencil thicker. She generally apprised herself of the length of an object by holding it at one end and then drawing it through the fingers of the other hand.

Thus in estimating thickness we again notice the unreliability of kinaesthetic sensation as a guide to the relative position of the fingers measuring the thickness. When a blind person is allowed to use all his fingers for such measurements of thickness he again reckons it out by simply counting the number of fingers he must lay parallel in order to encircle the object to be measured, until all the fingers used are in contact with one another.

This girl, like Albertotti's young man, has another method of estimating lengths: she does not express the length to be measured in terms of the number of touch-units (in which already, at bottom, the time employed in counting must also be decisive), but transposes it into the time needed to draw the object with one hand, at equal speed, through the fingers of the other, and compares the times together. Nor, again, does the uniformity of this threading-motion have anything to do with the objective enlargement of the angle between the arms, which, though not spatially pictured, may well be kinaesthetically felt; it is controlled, rather, by the uniformity of the passive contact-sensation of sliding, the particular characteristic quality of which can be felt as the object slips through the fingers. For muscular sensations only provide a usable clue when at least one muscle or sinew is definitely felt as tensed or relaxed, and hence especially in the region of both terminal positions of the limbs, as when the touching fingers or arms are either almost at full stretch or approaching maximum flexure.

DIDEROT [6] says of his blind man:

> He is an extremely good judge of the weight of bodies and the capacity of vessels; and he has trained his arms to be such an exact balance, and his fingers to be such skilful compasses, that in this kind of statics I would always back our blind man against twenty persons with all their eyes about them.

Since the man's trade was to make and bottle liqueurs, his skill in estimating the capacity of vessels is intelligible (being based on the *relative* weight before and after 'filling'); but it is only to be understood

as due to the aid of such auxiliary ideas as he had systematically developed in this connection for practical purposes, making use of all that the sighted could tell him. Thus in the activity of 'filling' bottles, for example, acoustical aids, in particular, also play a very considerable role.

In these last three cases, therefore, we obviously have no apprehension of space during the successive touching of spatial objects, but on the one hand time and number as accessory ideas (the latter being in any case closely connected, in the blind, with ideas of time) and on the other hand weight and textural quality as genuine perceptions appropriate to the sense of touch.

We also get exactly the same picture in AHLSTRÖM [51]:

> Immediately on first touching them with her fingertips she named the objects handed to her, such as a knife, spoon, watch, brush, coin, glass, apple, egg, pencil, ring, doll, etc., by their correct names, and also the materials of which they were composed, such as wood, iron, glass or cloth; she could also detect small differences in weight with great facility. But she found it difficult to say which of several objects handed to her at once was longer or thicker than the rest.

Again, therefore, we have recognition 'at first sight' – thanks to the refined perception of differences in quality or weight – but no power of conveying to herself in any way the length or thickness of an object. Nor was she able to tell the tactual size of an object from having held it between her two arms; her notions of objects had, as it were, no sort of spatial relation to herself. Her tactual experiences had given her so little consciousness of space, that three and a half months after the operation she was still unable to grasp the solid nature of three-dimensional bodies.

GAYET [40] writes similarly, of his sixteen-year-old girl patient:

> Nor has she come near to acquiring all the concepts which her remaining senses might have furnished her with, and the chain of her thoughts is neither lengthy nor complex. To give an idea of it, I may say that I have found in her no notion of size, for example, not even within the narrow limits which she might have encompassed with the aid of touch. Thus when I asked her to show me how big her mother was, she did not stretch out her hands, but set her two index-fingers a few inches apart. The same gesture was employed to show me what she took to be the size of a book. And yet her sense of touch was not at fault, for she was continually observed to run her fingers over the objects given to her, and, as we shall see below, she has given us quite manifest examples of her tactile sensitivity.

Gayet records such an example in describing the following occurrence during the visual tests:

> I brought an uncle, of whom she was very fond, to sit by her bedside and told him to remain quite still; I stood behind him and told X to look at the face in front of her. 'That's your face', she said at once. 'Reach out for it then', I said. She stretched out her forefinger and ran it over a quite small surface of her uncle's cheek, and immediately her face beamed and she cried: 'It's my uncle!'

These two passages show quite plainly that, left to himself, the blind patient takes no interest in the shape of tactual objects unless he is urged to do so; and that, on the contrary, it is chiefly by means of its tactual *quality* that he is able to recognize the object for what it is.

SCHNABEL I [33] likewise lacks

> completely the concepts of large and small, near and far, thick and thin, round and angular, smooth and rough, blunt and sharp, etc.

But we can scarcely introduce this case here, since apart from spatial concepts he was also deficient in qualitative ones, and even after the operation gave every impression of being feeble-minded. The blowing-out of a candle-flame, prior to operation, appears to have been more of a party trick, evoked as a reflex, than a conscious piece of behaviour related to a consciously estimated distance; for otherwise he must already have had an optically derived awareness of space.

Of his second case [34] SCHNABEL says:

> She gave rapid and correct estimates of the relative sizes of a number of objects, and also of their number.

But this case too may be left out of account, since she only went blind in the fifth year of her life and still had a certain residue of vision shortly before her operation. For if she could recognize colours and could locate a light-source some six yards away, she must likewise have had a visual awareness of space.

DAVIEL'S statement [7], made in 1762, is quite categorical, being based upon the evidence of twenty-two such cases operated on by him. He declares that the congenitally blind 'have no real idea even of the smallest objects'.

BEER [10] considers himself to have quite unambiguous evidence of the spatiality of tactual impressions in the blind man's mind, in that

> even while still blind [such patients] readily learn to distinguish by touch between the outlines of mathematical figures and are able to trace out in the air with a finger triangles, circles, squares, rectangles, angles, etc., all with great exactitude.

Such feats of planimetry on the part of the blind are readily brought forward as evidence of tactual space; but they afford no such compulsive proof. For in outlining the above-mentioned geometrical figures the tracing finger and hand remain more or less motionless, whereas the arm is subject to kinaesthetic and muscular sensations having a quite sharply defined rhythmical sequence and exhibiting equally characteristic differences among themselves; the whole hand is alternately drawn in and extended by the arm-muscles, now carried in to the body, now shifted sideways, now switched to and fro in sharp, zig-zag lines, now gently traversing a sinuous curve. Once the blind man has followed out a contour of this kind with his finger, he consciously remembers the whole kinaesthetic sequence gone through by his arm in the process and can reproduce it without further ado in exactly the same fashion, without any need for him to become aware of this tactual sequence as a figure in space. That in the reproduction of such series of arm movements the patients have no idea of the shape can be seen from the fact that they can make nothing of real figures after the operation. The visually given shape is something entirely new to them, for which no links are available to them from their tactual experiences. Even Beer is surprised at this:

> But it is strange that these very patients (14) who, while still blind, were well able by touch to distinguish a square from a parallelogram and a jagged line from a curved one, and could describe them in the air with a finger, did not learn so readily to distinguish all these figures by sight alone, without the assistance of touch; for the parallelogram cut out of white paper they continually pictured in the air as a rectangle, and the wavy line as a jagged one.

From the above account it is not perfectly clear, unfortunately, just how this experiment was conducted. But it seems as if the patient's tactual memory is best at retaining the sharply accentuated, jerkily executed motions of the arm, and therefore reproduces most readily when the structure of the optical figure presented seems to offer some point of association with these. The fact that, in general, some note had already been taken of contours, shows that these experiments must have taken place at an advanced stage of visual experience.

FIALLA [27] states that the congenitally blind patient 'has no exact notion even of the shape of his own body'. His own hand, which he has used and touched on innumerable occasions, is a mere instrument for grasping and feeling, there being no sort of awareness of its shape; he only recognizes a hand by sight when he knows from his own passive

feelings that it is his own hand that is held up before him; i.e. he does not 'recognize' it at all, but merely reports something that he knows from feeling; in so doing he encounters his own hand for the first time as a *shape*, and that by means of sight.

In a final summing-up of his six cases, Fialla then says:

> I must acknowledge first of all that in none of my patients could I detect innate ideas. When the organ of sight is lacking, no clear idea of our external world can develop in the individual, any more than the idea of sounds could develop in another man who lacked ears. . . . Touch is unable to replace the missing sense; it does not extend beyond arm's length and restricts the blind man's knowledge to his immediate environment; it acquaints him with the form, the surface, the temperature and the consistency of the bodies he touches; but he remains nonetheless in the completest darkness as to all that we speak of as the external world.

This last passage might seem to be somewhat contradictory of what has gone before; for first the patient derives no clear notion from touch about objects in the outside world, and then it is said to acquaint him with the form of the object he touches. But taken in conjunction with the earlier remark about the patient's lack of any idea of his own body, this last passage must evidently be taken to mean that Fialla is intending to establish the objective field of the sense of touch, without wishing to imply that the blind man is also subjectively aware of this objectively given tactual field as a tactual *space*; his statements about form admittedly refer to the objective form; it is a question, merely, of how much the blind man understands of this; such insights into the form of the object merely help him to formulate statements about what is called the 'form', but without any need for him to be spatially conscious of the form itself. In conclusion, Fialla again observes:

> He really has no idea of the external world, and the promise to enable him to see this world and everything about us has so little imaginable meaning for him, that if the operation were to miscarry, it would surely be met with less serious disappointment than in the case of someone who had only lost his sight in later life.

Since Fialla gives no details of individual experiments, it cannot be decided with absolute certainty whether he himself is merely referring to the impossibility of picturing tactual objects as visual shapes, or really wishes to make a categorical restriction of all instances of shape to the space of sight.

UHTHOFF [45] has also examined his cases in great detail from this point of view. He expressly remarks of his first seven-year-old patient

that his intellectual upbringing had been retarded, though he could not in any sense be described as an idiot. And yet his spatial concepts were as undeveloped as those of Schnabel I.

> From feeling alone it seems virtually impossible for him to arrive at any judgement as to the size of his body or other objects; and his utterances on this subject are quite extraordinarily hesitant and uncertain. It appears, in fact, that he still lacks these concepts, and lengthy and very thorough instruction is required before he is even partially able to grasp what it is all about and what answers he is supposed to give.
>
> As regards knowledge of the forms of objects, mathematical figures, etc., the boy seems to be lacking, at first, in all concepts, nor can he tell by feeling whether a thing is round, square or triangular. . . . After some three days of practice he is just about able to distinguish correctly, by feeling, between a round object and a square one.

Uhthoff calls this a 'defect in his intellectual upbringing'. But this description would be justified only if it recorded the objective fact that there had been a failure to bring these concepts to his notice. The case merely shows once more that spatial concepts have to be artificially inculcated, that tactual manipulation as such does not lead to a spatial apprehension of the object touched, and hence that spatial concepts must always remain something essentially alien. The boy has never thought spatially on his own account, nor has he been encouraged, as a substitute for this, to take note of the relations of order among things in terms of a schema, to which other patients on our list have been driven by their own urge to think.

The facts concerning this boy led Uhthoff to make further inquiries into the problem of tactual estimation of size in the case of other patients of good intelligence:

> It was found that a 19-year-old girl, already blinded from her earliest youth, made considerable errors in this regard, whereas a young man of 21, blinded only three years earlier, estimated sizes in this fashion with tolerable accuracy; after feeling the object in question, his procedure was first to lay the fingers of both hands together and then to separate them so far as to suggest the approximate size of the object.

Uhthoff attributes the greater accuracy of this young man's estimates to the fact that he had earlier been able to control them by eye. He is certainly right in assuming that this patient still possessed a visual awareness of space. His mode of procedure, however, is typically tactual. What he is estimating here is not some sort of visual memory-image, but, as in von Hippel's case (*cf.* p. 50), the time required to restore his hands to their initial position after he had brought them

together. Apart from that he also possessed thereby a control in the shape of muscular sensation, since in touching the object he held it between both arms. His female fellow-subject, on the other hand, seems to have made use only of this latter criterion. For her the task consisted in rediscovering the same position of her limbs, relative to the body and to one another, that they had occupied when measuring off the object from both ends. To assist her in this she had a certain feeling of tension in the muscles and an awareness of weight. Objectively speaking, her degree of error must have increased in proportion to the length of leverage involved. With the fulcrum at the shoulder-joint, so that the length to be assessed is grasped at each end by the whole arm, the estimate will have been more inaccurate than with the elbows pressed in and pivoted from there. In each case, however, the task is of a quite different sort for a blind person from what it appears to be to a sighted one. Even if only small mistakes were to appear in such tests, there would be no occasion to doubt that what the blind patient here reproduces from memory are impressions experienced within his own body, and not lengths abstracted from the tactual object and stored in consciousness as ideas.

UHTHOFF'S second case [56], although only five, had already, in his opinion, acquired a partial grasp of those 'spatial concepts' which were still lacking in the first.

> It could plainly be seen of this boy that by dint of feeling he had a correct notion of form, though he certainly could not judge it correctly by eye alone.

Uhthoff's examples show, however, that the boy was merely asked the difference between 'round' and 'not round'. Indeed he gives no usable details of this case which would enable us to analyse it more thoroughly.

In order, however, to fill in this fragmentary picture for himself, UHTHOFF attempted a detailed psychological study of a case of complete amaurosis due to *microphthalmus congenitus* (a woman of thirty-seven) [57]. In referring to the content of her sensory ideas he speaks here of acoustical and tactual 'memory-images'. But what is involved in both cases are temporal sequences of impressions, which in memory are invested with a certain unity. She notices and remembers only the qualitative (the sound of a voice, the pressure of a hand). On being asked what she thinks a man looks like, she says:

> I think of a child that I have often embraced, and transpose this for myself into a larger size.

The notion of 'size' seems to be bound up, in her case, with the sensation of having to stretch out the arms 'wide'. She also applies this to trees and clouds. As soon as she is seriously questioned about the shape of anything, she begins to quote what she has learnt from books (the Bible) or from what others (the parson) have told her. Her substitute-ideas also derive from these sources; thus she takes 'beautiful', for example, to mean what can only be brought about with great trouble.

As to the main question, concerning the spatiality of her tactual impressions, this report is also silent.

By contrast, there is a passage in LATTA [60], which deserves special attention here, since it is the only one in which the patient himself refers to a consciousness of space. It runs as follows:

> When asked to distinguish between a ball and a toy brick, he looked at them attentively for a considerable time, his hands meanwhile moving nervously, as if he were trying to translate what he saw by comparing it with an imaginary tactile impression, and then he described both correctly [i.e. the one as round, the other as square]. He explained that he was so much in the habit of handling objects that he had come to have a 'notion in his mind' regarding the form of things.

This case of Latta's is certainly among the most interesting of them all, since his patient had entered more than any other into practical life and possessed a very decided urge to think and excellent powers of combination. Latta himself says of this observation that he had noted that already prior to the test his patient had acquired a certain amount of visual experience by examining straight chair-backs and the curved outlines of faces; all the same, he does not think that, in view of the restlessness of his head and eyes, the man could have arrived at a visual notion of straight and curved lines, and therefore does not consider that this small store of visual ideas can be adduced to explain the recognition of the two visual shapes. He observes, rather, that as the test is commonly presented it could not have been difficult for a thirty-year-old man, accustomed to systematic thought, to identify two such structurally diverse visual impressions as those of a ball and a brick by means of imaginary tactual manipulations.

Thus it seems as if the test was so presented that the patient knew what sort of objects they were that lay before him, and had only to decide which of the two was a brick and which a ball; and to help him in this task he had the knowledge that a ball was called 'round' and a brick 'square', and knew by touch the qualitatively distinct series of im-

pressions produced in his touching hand by a round and an angular object respectively.

Latta thus assumes that his patient solved this problem without the concurrence of previous visual impressions and accounts for it as a pure feat of thought, intrinsically possible to any intelligent patient of this kind. Here he relies on Abbott (17), who observes on this point,

> that if the blind are capable of acquiring the ideas in question, they will, on being made to see, be competent to name correctly the globe and cube which they have previously felt. Consequently if, upon being fairly examined, they appear incapable of doing so, it will follow that the defect is not in sight, but in touch, not in their new sense, but in their old ideas.

Although the other cases fail to confirm this assumption, that a systematic interrelation of all the individual impressions could really lead to the acquisition of certain spatial concepts, Abbott's words contain the admission that the impressions gained from an object by touch alone do not in themselves have any spatial character favouring the apprehension of shape. Granted that the experiment itself was really conducted in the manner described, and that none of its details escaped observation; granted further that the patient had really not yet acquired the visual spatial images of 'round' and 'square'; even so, what the young man will have acquired by means of this intensive intellectual elaboration of his tactual impressions will hardly have been more than a clearer awareness of the structure of tactual objects. And this he will have attained by a systematic interrelation of his successive impressions of these objects, with a view to coordinating the tactual sequence mentally into an integrated pattern of order. What has developed in the blind man in this instance is a typical schematic image, which in this case emerges with particular clarity. The patient possessed such a schema, for example, of his own face, and this helped him in identifying his first visual image after the operation. Dr Ramsay, who operated on him, writes:

> The first thing he actually perceived was the face of the house-surgeon. He says that at first he did not know what it was he saw, but that when Dr Stewart [who was bending over him] asked him to look down, the sense of hearing guided his eye straight to the point whence the sound came, and then, recalling what he knew from having felt his own face, he realized that this must be a mouth, and that he must be looking at a face.

And Latta notes:

> It should be added that he felt his own face with his hand while he looked.

This description is probably not quite complete, since if the patient's hearing had really led him aright, he would not have needed to bring in touch to assist him. What guided him, apart from the voice, will have been the visual perception of the changes, due to oral movements, simultaneously occurring in the surface on which his eyes happened to be directed. He notes the acoustical and visual impressions simultaneously, and relates them causally to one another; remembers that speech comes from the mouth, and that changes occur in his own mouth when speaking; guesses that it is a mouth in front of him; feels his own mouth (probably making speech-movements at the same time); recognizes that the 'movements' felt in his own mouth correspond with the changes seen; now knows that the moving part is the mouth and the whole visual image a face; and thereupon runs over the whole schema of his own face, comparing it with his visual impressions, possibly in the sequence mouth, nose, eyes, which actually represent a quite characteristic tactual schema.

But in making this scrutiny he is already in possession of the visual ideas of straight and curved lines, and knows the look of what has previously been felt thus; in the course of this experiment the tactual schema has given place to an apprehension of shape – it has acquired a spatial character.

So too, in the experiment with brick and ball, he will already have possessed a certain visually acquired consciousness of shape; and though we need not doubt that his recognition of the visual shape really took place as described, it will have been helped out by a modicum of visual experience. And if he himself claims thereafter to have already acquired concepts of shape by tactual means, some part in this will doubtless have been played by the experience gained from his own experiment, in the manner just described, without the patient himself being clearly aware of the fact.

But this example, like all his behaviour prior to the operation, shows how systematically Latta's patient had made use of every single impression to assist him in orientating himself in space or in identifying objects. Already before the operation he had undoubtedly striven by all the means available to him to acquire a quasi-objective apprehension of things in the world he inhabited, and in which he earned his living;

and had really gone as far in this direction as a person born blind can ever hope to do. He himself was convinced that in his schema derived from tactual objects he had already reached the true notion of shape. But his behaviour during these two experiments shows that in fact it was no more than a schema; prior to operation he possessed no idea either of horizontal and vertical or of round and angular, but only the tactual relation between upright and horizontal, and the distinction between round and angular tactual sequences; no absolute spatial concepts, but only relational concepts, ordered sequences and schemata.

But a tactual schema of this sort does not afford even the vaguest notion of shape in the object touched. For both this case of Latta's, and others also, demonstrate beyond all doubt that such a schema has so little of the really spatial about it that it cannot be applied forthwith, once the operation is over, to the spatiality of sight.

3. Other Indications concerning the Tactual Conception of Space

A. REFLECTIONS OF THE CONGENITALLY BLIND

This case of Latta's raises the question how far the other patients, in their *reflections on the world of sight*, are also preoccupied with the problem of shape and spatial depth. Since the patient is in continual contact with sighted persons, and learns from them everything which gives content to his own existence, and is instructed by them in the ordering of his sense-impressions and in their systematic evaluation, it is only too natural that an intelligent blind patient should begin to wonder what sort of an affair seeing may be; what it can be which gives the sighted person so great a superiority and certainty in commerce with himself and other people.

Thus Dufau, in his *Souvenirs et impressions d'une jeune aveugle-née* (Paris 1850), tells of a girl who only discovers at the age of twelve that she differs from other people in lacking a sense, and who now seeks to discover the nature of this unknown sense. The girl says:

> I posed myself a host of questions about this new and unknown state which had been described to me, and did my best to come to terms with them. In order to satisfy my doubt, I had the idea of trying a strange experiment. One morning I again put on a dress which I had not worn for some time, because I had been growing so rapidly then from month to month, and thus attired I suddenly showed myself at the door of the anteroom in which my governess was already working

> at the window. I stood listening. 'Good heavens, Lucy,' she said, 'why have you put on that old dress, that only reaches to your knees?' I merely uttered a few idle words and withdrew. This was enough to convince me that, without laying a hand upon me, Martha had immediately been able to recognize that I had again put on the dress that was too short. So this was seeing. I gradually recounted in my memory a multitude of things which must have been daily seen in the same fashion by the people about me and which could not have been known to them in any other way. I did not in the least understand how this happened, but I was at last persuaded. And this led gradually to a complete transformation of my ideas. I admitted to myself that there was in fact a highly important difference of organization between myself and other people; whereas I could make contact with them by touch and hearing, they were bound to me through an unknown sense, which entirely surrounded me even from a distance, followed me about, penetrated through me and somehow held me in its power from morning to night. What a strange power this was, to which I was subjected against my will, without, for my part, being able to exercise it over anyone at all. It made me shy and uneasy to begin with. I felt envious about it. It seemed to raise an impenetrable screen between society and myself. I felt unwillingly compelled to regard myself as an exceptional being, that had, as it were, to hide itself in order to live.

This feeling of uneasiness about the unknown sense, the desire to escape from the control which it gives to the sighted, is also frequently displayed in our cases, and leads, on occasion, to strange means of realizing this desire, for a time at least, to be able to lead a life of one's own, inaccessible to the sighted environment. So too, the reflections of our own patients are largely preoccupied with puzzling about the nature of this sense, the question, that is, how the sighted are able to perceive by means of another sense things which the blind themselves can only perceive by touch. This is also responsible for the attempts to produce light-sensations by mechanical stimulation, in order perhaps to fathom the secret in this way.

Space, on the other hand, either as space of figure or as space of depth, is hardly mentioned in the accounts of the thoughts of the patients prior to operation, which are in any case very scanty. The great majority have merely wondered how people and animals looked – this being so in the cases of Mesmer, Beer, Franz, Trinchinetti, Schnabel, Uhthoff IV, Raehlmann I, and the American Getaz case. But in fact they none of them say more than that they had fancied things to be 'different', or that they were surprised about the size of things.

We have already seen what to make of such apparent shape-imagery, due to touch, among the blind, from the case of RAEHLMANN I [46],

who claimed to have an exact notion of a horse, and then took a large dark ten-litre bottle for a horse at a distance of one foot.

Of the GETAZ case [65] it is reported:

> As Joan learned to use her eyes she found that almost nothing was really the way her hands had told it was when she was blind. She was confounded by the discovery that each new person who was brought in to see her had an entirely different face. She had thought that all faces were much alike except that some were rounder than others.

Here it is particularly obvious that the blind person only possesses a schema of such a thing as a face; and it is part of the notion of a schema that the schema of one face is pretty much like that of another. Where they differ to the touch is in the changing stretchings and bendings required of the touching surface of the hand in dealing, for example, with a long-headed person, in contrast to the relatively uniform posture of the hand with a round-headed one. The more 'bent' the hand must be kept in feeling around it, the 'rounder' the head is. The contrast is therefore given only as a relatively slight difference in the tactual sequence, which can thus only be discerned by a comparatively few sensitive blind persons, and not as a spatial distinction.

Since the patients can get no notion of shape from the sense of touch, their meditations about the nature of sight also lead to no result. They therefore stick mostly to a few assertions about sight that they have heard, and which seem intelligible to them. Whereas they have no sort of power of understanding the praise of this sense on the part of the sighted, they are inclined to exaggerate the disadvantages of which they hear, as that it is impossible to see at times that the 'sighted' call 'night'. According to whether the one or the other notions have made the greatest impression on the patients, they desire either to experience this marvel for themselves also, or adopt a quite passive attitude towards the possibility of gaining their sight. Thus CHESELDEN [5] reports:

> Before he was couched, he expected little advantage from seeing, worth undergoing an operation for, except reading and writing; for he said, he thought he could have no more pleasure in walking abroad than he had in the garden, which he could do safely and readily. And even blindness, he observed, had this advantage, that he could go anywhere in the dark much better than those who can see.

The street does not attract him at all, being associated in his mind with a great deal of noise and danger, without providing him in return with any sensory impressions; whereas in the garden he has a certain province of his own, in which at times he can entirely detach his thoughts

from the necessity of continually having to orientate himself, in which walking can be carried out quite mechanically, in which he can really relax and 'take a turn' with his mind completely at ease. He cannot grasp that the sighted person has no occasion to feel ill-at-ease in the street; he regards seeing merely as another sort of touching, which suffers only from the disadvantage that it cannot be exercised 'at night'. Whether in *our* cases the terms 'darkness' and 'night' have any sensory meaning for the patient, naturally depends upon the permeability of the lens, prior to operation, in each case.

And when DIDEROT'S case turns 'night' into 'day', he likewise does so in order not to have his own orientation disturbed by the numerous distracting impressions of the daytime. Nor does he particularly regret his lack of vision.

> If it were not for curiosity, I would just as soon have long arms: it seems to me my hands would tell me more of what goes on in the moon than your eyes or your telescopes; and besides, eyes cease to see sooner than hands to touch. I would be as well off if I perfected the organ I possess, as if I obtained the organ which I am deprived of.

Here again we may note the incapacity to picture great distances: he has heard, indeed, that the moon is so far away that no exact knowledge can be had of it by eye; but the moon is only a fable to him. Everything the blind man says contains a large admixture of mere hearsay, which he cannot picture, but which he has somehow adapted for his own general use. There is always a certain background of subjective experience, mingled with constituents of merely reported knowledge that he cannot test for himself. Thus when asked for his opinion on what eyes are, for example, he says:

> An organ on which the air has the effect this stick has on my hand. . . . When I place my hand between your eyes and an object, my hand is present to you but the object is absent. The same thing happens when I reach for one thing with my stick and come across another.

On a superficial reading, this passage might create the impression that this patient must have definitely possessed an awareness of space. But in fact these words have no real idea behind them: since the only real things, for him, are those with which he has contact by means of his hand or stick, he supposes that the air serves the eye as an extension of the means of touch, as the stick does for his own arm. Hence, therefore, the notion of the eye as a different sort of tactual organ. And hence too he can only interpret what he has heard about one object concealing another from a sighted person in accordance with his own tactual

experience. Having no conception of spatial perspective, he therefore has no idea either of the masking of one object by another; whatever the stick or the tactual beam of vision actually strikes, is present; everything else is absent, for both of them. The word 'between' therefore acquires another, non-spatial meaning: for when an object comes into connection with the tactile or visual organ, it cuts the latter off from the possibility of interacting with other objects and is therefore situated 'between' the organ and the other objects.

The whole of Diderot's report is full of such examples, which show that though the blind man does indeed use our expressions, he does so as an uneducated person employs foreign terms, without knowing what they mean:

> If he attaches no idea to the terms he makes use of, yet he has the advantage over most other men that he never uses them wrongly. He speaks so wisely and so well of so many things absolutely unknown to him, that . . .

In this, however, he is strongly influenced by the endeavour, which he shares with many of our cases, to deceive the sighted so far as possible as to how difficult it really is for them to remain in contact with their environment; they pretend to themselves, and to others, a greater security than they possess. In actual fact, however, sighted and blind persons are always talking at cross-purposes, owing to the differences of sensory impression in each case, despite a common language. In the American GETAZ case [65] we read:

> While Joan is able now to tell us of the curious notions the blind entertain of the world about them, she can't enlighten her blind friends much about the new world that she has just graduated into. 'You can't tell a person how anything looks unless he has once had eyes that saw,' she says. 'The words don't mean a thing to him.'

She is indeed fully entitled to say this, because in doing so she is merely repeating her own experience:

> When she saw that a tree was ten times as tall as her father and mother she thought her eyes were playing a trick on her. Of course she had been told and knew perfectly well that trees grow to great heights but descriptions of anything taller than a blind person can reach with a stick are just empty words.

Unfortunately it has not occurred to any of those who have worked on the other cases to ask the patients themselves where the difference lay, for them, between the spatial data of the tactual and visual spheres. Since the patients include quite a number of educated people of

mature age, a great many important conclusions might perhaps have been gathered from them on this very question. And we should not be obliged today to rely merely upon the more or less casual observations of the reporters, and on the results of the few experiments made before the operation, as a basis for inductive conclusions as to the nature of tactual space.

B. ABSENCE OF TRANSFER IN THE POST-OPERATIVE RECOGNITION OF SHAPE

The problem of tactual space can also be raised in another way. For if it be said that the patient derives an awareness of the shape of objects, and of spatial depth, from his impressions of touch and motion, then he ought not subsequently *to find anything basically new in the visual field.* One cannot maintain that the blind man has an awareness of space, save only that it differs widely from that of the sighted. We can only call something an awareness of space if in all essentials it conveys to the mind a notion of real space. It must therefore be insisted, if the term 'tactual space' is to have any meaning, that a blind man, however he may have formed his awareness of space, if he has one, should not find himself confronted after the operation with the space of sight as something entirely new and completely incomprehensible to him; not to say that he ought to be able to recognize his old tactual space in the new visual one.

But even to the question thus posed our cases yield not a single positive answer. On the contrary, HEYFELDER [22] gives the following typical example from the case of his seventeen-year-old girl patient:

> I showed her a brown cross on a white ground; she gave the colour, length and breadth and also the shape approximately, but not the name 'cross'. I made her trace the shape with a finger, but she dissected the cross into a long perpendicular with a spike sticking out to right and left; finally, when I had many times guided her hand, first down the vertical from top to bottom, and then from left to right across the horizontal, whereby the lines actually crossed and produced a (tactual) imitation of the sign of the cross, which she made daily upon herself, it eventually occurred to her that the brown figure was a cross. And by this discovery she was endlessly delighted, as by every other she made.

We see here, therefore, that the girl had taken infinite trouble to comprehend the visual figure, but could not recognize it because she had had no idea of shape in her mind before the operation, although she had daily made the sign of the cross for many years and had certainly also handled many crosses. What she had been aware of then consisted,

therefore, in the first place, in nothing more than the kinaesthetic sensation of the two suddenly off-set movements in their schematic order, accompanied by felt changes in the muscular tension of the hand and forearm. Later, indeed, she will probably have grasped the schema, but the latter had so little imagery about it that it gave her no help in identifying the visual shape.

C. ABANDONMENT OF TACTUAL HABITS AFTER OPERATION

A final indication may serve to show how much the whole life of the blind man in the spatial world consists merely in painfully constructed schematic connections, and has no real awareness of space behind it. This indication lies in the fact that these *schemata*, being merely *aids* enforced by necessity, are dropped almost at once and *cease to be applicable*, when the patient consciously finds himself in the new world of visible objects, where, for the first time, his visual impressions give him a real conception of space.

This emerges particularly clearly in LATTA I [60], which we have already discussed in some detail. We have seen how this patient had constructed, out of the most manifold impressions and every possible scrap of knowledge, a quite firmly articulated system within which he moved with a wonderful appearance of certainty; but it was bound to fail him at once, as soon as he found himself in a field which could no longer be grasped by means of this system. The system in question proved very useful to him after the operation in grappling with visual reality, and also brought it about (which surprised Latta greatly) that he very soon learnt to grasp and estimate the spatial relationships of visible objects, and also got his bearings very quickly within the visual world.

But this very patient was also extremely quick to lose the capacity to find his way about by the help of touch alone; he lost all certainty and confidence in the methods he had previously employed,

> so much so, that he does not know what he would do if he were again to become blind.

The same applies in MESMER'S case [9]; this patient also had already acquired an extensive conceptual knowledge and very quickly found herself at home in the visual world, but because of her sensitivity to light was obliged for most of the time to go about with eyes bandaged,

> but dares not take a step forward, whereas previously, when blind, she had walked about quite confidently in her familiar chamber without guidance from anyone.

BEER [10] also confirms this, in general, of his fourteen patients. So too, it is said, in the case of FIALLA III [29]:

> So long as he had been blind he went about alone through the streets, came back home, travelled without difficulty to all parts of the town; but when he could use his eyes he no longer knew where he was and got lost; he was compelled to ask the way from passers-by.

Now how are we to interpret this sudden transition? It might be supposed that the patients' earlier sensory impressions, with which they had assisted themselves, had retired into the background in face of the new visual impressions. But this is contradicted by the many cases in which touch still persists for a long time after the operation, because the patients protect themselves against these visual impressions, which they do not yet know how to evaluate. The notable thing is that it is always one sense alone which dominates over the others; to begin with it is still touch; but as soon as understanding of the visual impressions has entered, it is all over with tactual orientation. This is shown in the three passages cited: these patients have not, as it were, abandoned their previous sense-impressions unwittingly, but would gladly go on using them for assistance as before, if they could; but they feel themselves disabled from doing so. Is the reason, then, that these impressions suddenly cease and somehow leave their recipients abruptly in the lurch? This is certainly ruled out; an organ developed to the full height of its capacities does not lose these powers so long as no pathological symptoms intervene. And if the patients had hitherto pursued their movements in space in the same mechanical fashion as the sighted do, proceeding reflexively, as it were, on the basis of the impressions received by the various sense-organs, then it should also have been possible for them, after the operation, to do so with their eyes closed. And if in fact they can no longer do so, once they have begun to orientate themselves in the manner of the sighted, that is again evidence for the fact that such sensory stimuli only play a very subordinate role for the blind man, and on the contrary, that in moving about he has to carry out a continuous process of thought in order to remain permanently within his schematic field. He must first obtain a constant supply of such auxiliary impressions of a tactual or acoustical kind, and continually apply them to his schema and use them as a basis for his further motor behaviour.

It is this constant concentration of thought which the patients are no longer capable of, once they have completed the transition, in more or less conscious fashion, into the visual sphere; especially once visual experience has also taken possession of their imagery, and accompanies

them throughout with visual images. Once this happens, the visual contents have become the sole source of all sensory reference, and can no longer be repressed; the living colour and richness of the new imagery increasingly overspreads the whole range of previous tactual impressions. When the patient has once acquired them, these images never again leave him; they are continually present to his mind, and even transform his dreams. They disclose his previous schema to the patient as a construction, by whose aid he had sought to grasp the orderly connection of the successive sense-impressions impinging on him, and to fuse them into a unity in his mind. This predominantly intellectual creation of the mind has now become untenable, having shown itself, by comparison with the new truth of sensory experience, to be too remote from reality.

When, therefore, CHESELDEN [5] says of his patient that 'he did not soon lose this quality' (of going anywhere in the dark), the reason for this will be that for a long time he will have had no visual imagery; that it took him a long time for sight to become the most important of his senses. This can also be gathered from Cheselden's observation that his patient had great difficulties in learning to see, and had painfully to learn his visual images by heart, like letters. Indeed, when he says spontaneously a year after the operation, on Epsom Downs, that he has discovered 'a new kind of seeing', it would appear that at this moment only did he first grasp the true meaning of sight.

D. MODE OF SCHEMA-FORMATION

One thing emerges clearly from the accounts already given of our cases, and that is the existence of a basic distinction between what one may call a real consciousness of space and what is actually given to the blind patient in the way of 'spatial' characteristics: what we have referred to, on the strength of our reports, as the *schema*. In order to illustrate this notion more clearly from our material, we shall add some further passages calculated to bring out positively what is presented to the blind man in this schematism.

Here too there is a particularly characteristic passage in the already mentioned American case [65]:

> Joan had felt of the trunks of trees [*sic*] and of the trunks of her parents and supposed that they looked very much alike. They had a round trunk like a man and limbs that stuck out like arms and ended in leaves instead of hands, but if she had remained blind she would have gone through life with the vague impression that the tallest tree was about

ten feet high. One of the important pieces of information that she imparted to a blind friend was this discovery that men do not really look like trees at all.

The sighted person would discover almost nothing in common between a man and a tree; for the blind man the resemblance lies in the fact that they have the same schema: a trunk without edges which can be wholly or partially embraced in the outstretched arms; various branches emerging from this trunk, which in a man are mobile and in a tree are firmly attached; and at the end of these branches a termination consisting of fingers in man, and of leaves in a tree. Both objects therefore belong, for the blind, to a large group embracing numerous objects (e.g. candelabra, rounded cloak-stands, etc.) which all have one thing in common, that they are built upon the same structural plan, according to the same schema.

A group of this sort, with a common schema, embraces the most diverse items; their differing tactual quality leads to their recognition, not their shape. Of his own accord, the blind man would not concern himself at all with the problem of shape, were he not induced by the sighted to pay attention to anything that can give him a clue so as to determine what the sighted speak of as the shape of the object.

Equally characteristic, but this time for the apprehension of a larger surface-area, is the passage in WARDROP I [15]; it is even more important, because this schema of the fifteen-year-old blind deaf-mute contains virtually no components other than tactual ones, and therefore brings out very clearly the purely constructive character of the schema:

> There is a certain range around the manse which he has minutely explored by his organs of touch, and to any part of this space he seems to walk, when he pleases, fearlessly and without a guide. I believe his range does not yet extend beyond two hundred yards in any direction; but there is probably not a day elapses, during which he does not cautiously feel his way into ground which he had not explored before; and thus gradually extends his yet very circumscribed field of observation.

Here, therefore, there is a purely temporal interrelating of qualitative tactual impressions.

II

THE SIGNIFICANCE OF RESIDUAL VISION IN CATARACT PATIENTS FOR THEIR CONSCIOUSNESS OF SPACE

It remains for us to inquire whether the spatial consciousness that can be demonstrated in a number of cases, prior to operation, is of tactual or visual origin. As already mentioned at the outset, the empiricists have rejected a large number of such cases as convincing evidence for the problem of visual space, on the ground that, being cataract patients, they would already have had adequate powers of vision prior to the operation, and therefore would already at this stage have acquired a notion of visual space.

1. Brightness alone Given

What they will have possessed, as cataract patients, is above all a more or less strong *sensitivity to differences of brightness*, which extends so far, in some instances, as to enable them to indicate the objective direction of the light-source. The question now arises, how we are to interpret this apparent localization of visual direction on the part of persons otherwise blind; whether, when the blind man points in a definite direction, he is also consciously aware in himself of this region of maximum brightness as a direction stretching out into space, whether he thereby lawfully acquires a consciousness of spatial depth.

In order to settle this question, it is therefore necessary to separate out those cases having sufficient sensitivity to light to be able to state the objective direction of the light-source, though they lack any ability to see either colour or shape; and the cases thus separated must be tested to see whether, by means of this ability to give the direction, they had already achieved what in this case would naturally be a visually acquired consciousness of space.

Unfortunately, the details as to the vision of the patients before and

after operation are extremely fragmentary, and besides, exact experiments as to power of localizing direction, seeing colour and perceiving shape have only been undertaken in some of the more recent cases. Hence the only cases which definitely fall into this group are those of Wardrop II, Nunneley, Ahlström and Latta; the other cases having no perception of colour also had no localization of direction and were in some instances almost amaurotic, like the case of Mesmer and some of those of Uhthoff.

Of these four cases, WARDROP'S forty-six-year-old female patient [16] could only give the direction of a very bright light-source. Wardrop undertook no exact experiments, either before or after operation, but from her whole behaviour after the operation, and from various already quoted remarks in the report, it emerges sufficiently clearly that prior to operation she had no awareness of space, and had indeed attained to hardly any knowledge at all of spatial connections.

NUNNELEY'S case [21] is very similar, his nine-year-old boy having acquired no consciousness of space, but only a somewhat vague knowledge about structural connections.

AHLSTRÖM [51] made definite experiments with his nine-year-old girl, and came to the same conclusion; she obviously did not understand at all what the doctor meant by his questions about distance.

More interesting in this connection is again the case of LATTA I [60], whose thirty-year-old patient, as we have several times seen, had been particularly methodical in organizing all his sense-impressions into a system which gave him great self-assurance within the sphere covered by it. This man had undoubtedly taken every care to exhaust completely the possibilities afforded him by his sensitivity to visual brightness. We have already established that, tactually speaking, he had no consciousness of space, though his system of schemata was unusually differentiated for a blind man. But there appears also no reason to suppose that his visual sensations had in any way contributed to the development of these schemata. He seems also to have had no visually derived idea of space, so far as can be gathered from Latta's account, and from the patient's helplessness outside the boundaries of his own system. At all events he had plainly had no idea of the actual size of the area covered by means of this system, though he had traversed it almost daily in the course of his work. Even though the operation was conducted in a place unfamiliar to him, his behaviour in regard to the visual field offers abundant evidence for the conclusion that he had no consciousness of space. In Latta's own report we read:

In general things seemed larger than he expected; but the great extent of space did not impress him until he had left the hospital.

If Latta makes this observation, at a date some two months after the operation, when the man had had innumerable experiences within a narrower visual field, it can readily be concluded from this that the spatial data which he had had before the operation in no sense corresponded to objective space. He had known, indeed, that there was such a thing as 'space', in which he moved about, and had thought a great deal about the nature of this space; but the result of these lengthy meditations had not given him any idea of true space, but had led him to construct for himself a sort of substitute-space, or schema, and to satisfy himself that in doing so he had thereby attained to what the sighted refer to as space and shape.

In any case it can be stated, quite independently of whether he had spatial consciousness or not, that at all events he had not acquired this knowledge of space as a result of his capacity to determine the direction of a strong source of light, but in consequence of his meditations, and of the fact that he also attended to the most insignificant impressions from all sensory spheres and retained them in his memory in order to fit them continuously, by skilled combination, into his schema.

We may therefore say that the mere discovery of the posture of the head conveying the greatest intensity of light to the eye does not imply any real awareness of the visual direction of the light-source, and in any case does not suffice to give the patient a visual notion of space, or to lend his tactile perceptions a consciously spatial character.

This is only to be expected, indeed, since at bottom the cataract patient who has acquired this art of determining the direction of a light-source, has no advantage over those who are unable to do this. For his eyes cannot, on this account alone, determine the 'direction' of the light-source, since they are incapable of fixating it, but oscillate aimlessly, each in its own orbit. This is not to deny, of course, that our cataract cases can perceive brightness objectively only in a sort of shapeless extension. It is like a very dim greyness in the eye, which lights up a quite limited field to a barely noticeable extent. This field lacks all structure and all depth, and is either not noticed at all, or can be of no practical significance to the patient. It is a sort of miniature space, but there are no things in it; it does not suffice to establish any relations with the environment, either with tactual or visual objects. This sort of light-sensation is basically not 'seeing' at all, but a qualitative state of the eye; the light is not outside his body in a definite 'direction', but is felt

within his eye as a different light-intensity. And what seems to the sighted observer as discovery of the direction of a light-source is, for the blind man, the finding of the moment of maximum light-intensity. He turns his head slowly and notices the waxing and waning of the light-impression in his eye, and thereby finds the posture of the head in which the light is strongest in its effect on his eye. But for him it is always, subjectively speaking, merely something about the state of his own eye; he does not project it into a space, which under these circumstances is simply not yet given to his mind. If both eyes can be used, the procedure becomes easier, in so far as it is then more an accommodation of both eyes to the same intensity of light. But what he does here is in principle no different from when he sits, completely without light, in the centre of his schema, and from there can state objectively the various directions in which the objects within his immediate environment are situated. To the sighted observer, this too seems like a directional system, extending from his immediate front to the transverse axes on either side. But for the blind man these, too, are not directions pointing into space; they have nothing to do either with objective or with a subjective space; for him, they are dynamic 'directions' of action for his arms, in relation to desired or expected tactual impressions. These directions of action therefore continue unaltered in all postures of the body that he adopts, whatever his objective situation in space may happen to be. The objectively frontal area of his body is always that which can come into contact with objects and must come to terms with them, and his whole attention is therefore directed to this field; and what happens to lie behind him does not exist for him.

The reverse case, in which colour-vision is present, but no localization of direction, cannot be certainly established; for although Janin, Ware, Home II, Trinchinetti, Albertotti, Vurpas-Eggli and Miner give no details as to localization of direction on the part of their cases, we cannot conclude from this that it was lacking.

WARDROP assumes that his first case [15] had no visual localization of direction. But even supposing this to have been so at the time of the operation, he certainly had it at an earlier stage; for he would have been unable, for example, to hold light-collecting substances between his eye and the source of light if he had not had objective awareness of the direction of the light-source.

The only case which certainly belongs here is one of UHTHOFF'S [55]; but in this very instance Uhthoff gives no information about behaviour in space prior to the operation.

2. Brightness and Colours

We may hope for greater success, however, in examining those cases which, besides *light-sensation* and 'localization of direction', *also* possessed *colour-sensations*, though still lacking the perception of shape. To this group belong the cases of Ware, Home I, Hirschberg, von Hippel, Fischer, Raehlmann I, Schnabel and Augstein, as well as most of the cases already mentioned from Janin to Miner.

If we here renew our inquiry, whether the possession of light- and colour-sensations necessarily involves a visual awareness of space, we find that two of the later cases operated on by WARE actually did have an awareness of space. Ware himself says of them:

> [Though] no operation has yet been performed [on them], I find that the knowledge they have of colours, limited as it is, is sufficient to enable them to tell whether coloured objects be brought nearer to, or carried farther from them; for instance, whether they are at a distance of two inches or four inches from their eyes.

These words refer to two congenitally blind children of seven and eight, whose subsequent history is not, however, recorded by Ware. In a later passage he also applies this to his recorded case [11] of a seven-year-old boy, saying:

> The cases I have mentioned show that even the least knowledge that they have of colours is already sufficient to convey to them a certain notion of distances.

This question coincides with our own; and the remaining cases of this type will show whether he was right in this generalization, and what it is due to, when the patients acquire an awareness of space by means of colour vision.

In WARE II the girl is merely spoken of (after the first operation) as:

> discovering the colour of objects more plainly than before, but being still unable to distinguish their figure.

This case therefore tells us too little to be of use.

In HOME I [13] the patient was already sighted before the operation, and knew perfectly well how to use his eyes, though they gave him very little information. Home himself tells us that the boy knew no colours; this can only have been true in so far as he possibly did not know the exact designation of the colours. But when, under pre-operative testing,

which was limited, in fact, to indicating various light-sources (sun, fire, candle), he reported that one was 'redder' than the other, he thereby showed that he had perceived the differences of colour in each case. Moreover, when Home writes:

> The sun appeared to him the size of his hat. The candle-flame was larger than his finger and smaller than his arm,

this seems to point at first sight to a visual awareness of shape. But since, after operation, he had no idea of how to deal with the shapes of objects, it seems that in this pre-operative test there must have been some auxiliary idea at work. Home then goes on:

> When he looked at the sun, he said it appeared to touch his eye. When a lighted candle was placed before him, both his eyes were directed toward it, and moved together. When it was at any nearer distance than twelve inches, he said it touched his eyes. When moved farther off he said it did not touch them, and at twenty-two inches it became invisible.

Home's report is drawn up for the purpose of settling whether Cheselden or Ware was correct, whether primary vision is spatial or not; and he regards his first case as a vindication of Cheselden, assuming as he does that the boy had localized the light-source in his own eye. But from the report as a whole one gains the impression that the phrase 'touch the eye' is not spontaneously employed by the boy himself, but has been used as a set phrase by Home in his own questions; and that the boy's mind was not centred at all upon deciding the distance of the light-source, but simply on answering the question whether or not the light touched his eye. For even after the operation he showed himself so thoroughly drilled in this stock locution that he continued to repeat it on every conceivable occasion, however unsuitable. But the answering of this question could have had quite a different significance for him, and the answer a quite different meaning, therefore, from that which Home ascribed to it. One may readily convince oneself of this by repeating this experiment with the candle and simulating the condition of the patient by closing the eyelids. If, starting from some distance away, the candle is then slowly brought nearer, we first perceive only a wholly diffused gleam of light, having no distance at all, even for ourselves, so long as we repress our habit of judging by the intensity of a light-source with which we are already familiar. But at a quite definite point in its approach the light takes on a stabbing quality, 'touching the eye'. It is a dazzling sensation, such that even the sighted person is inclined to

localize the light-source in his own eye, because he feels pain there. To that extent, therefore, the utterances of Home's patient are perfectly in keeping; and it seems as if he had merely paid attention to this factor, without having any concern about the spatial aspect.

Under these circumstances, the report yields no definite conclusion as to whether the boy had a visual awareness of space; but this was presumably the case, since prior to the operation he already knew how to use his eyes as visual organs (fixation and convergence) and was therefore in principle a sighted person.

HOME's second case [14], a seven-year-old boy, he regards as parallel to those of Ware in respect of visual space, and concurs with Ware's opinion

> that where the eye has previously distinguished colours, there must also be an imperfect knowledge of distances, but not of outline.

Home made no tests on the boy; but when we read that in his first attempts to see after the operation he quite spontaneously peered at the cards held before him from nearer and farther off, in order to determine the point where he could see best, it may be inferred from this that even before operation he had already possessed an optimum power of vision at a distance empirically determined by himself, and hence was already furnished also with a visual awareness of space.

HIRSCHBERG I [24] exhibited a curious transitional stage at the time of his operation. In this boy, also seven years old, tactual and visual impressions were juxtaposed. His visual powers were less developed than in Home's cases, though under particularly favourable conditions (a bright lamp) he could also direct his eyes wholly upon an object and follow it in movement. Hirschberg appears to conclude from this that the boy must have been aware of a certain narrowly limited region of space, remarking *à propos* of the visual tests:

> Greater distances, on the contrary, he had thought much smaller on the previous day than they really were; obviously because he had had no suspicion that the senses could extend and feel so far.

But of the idea of shape he writes:

> He was perfectly able to distinguish by touch between bodies of different shapes; but he seemed to have no very clear conceptions of even the commonest kinds of form.

On the sixth day of testing after the operation he observes:

> This much is clear, however, that the visual training so far has already

> given him much clearer spatial concepts than he had before the operation and immediately after it. Only the day before he was quite unable to show me what 'round' and 'square' were; although previously he had often played with round balls and square cards, and had actually brought the latter into the clinic with him to play with, and although both words had entered and formed part of his vocabulary.

But this would imply that, tactually speaking, he not only had no awareness of spatial forms, but did not even possess schemata, whereas on the visual side he had already acquired a certain consciousness of visual depth. Or in other words, he had on the one hand been unable to enlarge the admittedly restricted spatial field actually given by sight, since he had no tactual awareness of space; and on the other, had equally been unable to acquire such a tactual awareness, despite the givenness of the visual field.

Thus if these assumptions of Hirschberg's were on the mark, this would provide the most telling proof that a true awareness of space can be given only by sight and not by touch.

But as it turns out, it seems that, prior to the operation, the boy did not even possess a visual awareness of space; for the pre-operative failure of visual impressions to influence his spatial concepts and mental life can be seen from the fact that touch-habits persisted in him for some time after the operation. By the same token, the ability to fix and follow a bright light may likewise have been a mere casual reflex, unconnected with any impression of depth; for if it had often occurred, along with a conscious use of the opportunities for orientation actually given thereby, the nystagmus would have disappeared, as happened with Home's patient and some of the other cases. This, therefore, is a case in which some power of sight was present, indeed, but was not consciously applied, and so did not lead to any awareness of space.

A similar state of affairs was exhibited in VON HIPPEL's four-year-old girl [23]. Only here the fact is better attested, since von Hippel, unlike Hirschberg, tested her powers of spatial vision before the operation. These tests show beyond doubt that in this girl also, her admittedly very limited powers of vision had not yet produced any true awareness of space, though she had already advanced quite far in the formation of schemata for her other sense-impressions, and was thus intelligent and quick at putting things together. But everything, in her case, was really just a matter of system, of the use of schemata, as is only too strikingly shown by the very fact that her pre-operative visual impressions were themselves dealt with in such a definitely schematic manner What she

spoke of as colour was only the difference in brightness between the light reflected from the object in question and the diffused light elsewhere in the room. The brighter part was 'white' to her, and the rest 'dark'. This exclusive attention to differences in brightness was also persisted in after the operation, so that even von Hippel was not altogether certain whether she had perceived colours or not.

Her conceptions of spatial depth were likewise schematic in another way. An object was 'near', to her, when she received a direct stimulus to the skin from it, and 'far' when this stimulus was not forthcoming from the object held before her (glass, plate, paper, handkerchief). Plainly, therefore, she was aware only of a very diffuse glimmer of light, and had either not observed or not attended to the gradual changes of size and brightness occurring when the object was brought nearer. At all events it is clear that her estimation of distance was not a visual accomplishment, but rested on the presence or absence of a characteristic sensation in the skin of her face; the idea of differences in spatial depth was clearly not present even when, having made her estimate, she bent or extended her arm in order to grasp the object. These will have been merely rooted associations between 'near' and bending the arm, or 'far' and stretching it. These movements themselves are equally little connected, by the blind, with spatial ideas, as we have already had frequent occasion to notice. Hippel himself refers here to *perceptio facialis*, a reaction of the sensitive facial nerves. But other stimuli may also have helped in this: heat-radiation, for example, from the hand of the doctor holding the object, or an audible change in the air-waves blanketed by it, or olfactory sensations. With the objects employed, such stimulus-effects are unavoidable, if they are not eliminated by special precautions, which von Hippel does not seem to have taken. In each case the child was concerned only with grasping qualitative peculiarities of this type, and not with spatial ideas. From this it may also be inferred that she had no tactual awareness of space either; for otherwise she would have applied it to her visual impressions.

FISCHER'S case [44] is less to the point here, since his eight-year-old girl only went blind gradually. Her visual trials show that she still had a great deal of reproductive material at her disposal. It is worth noting, however, that she seems never to have altogether lost her awareness of spatial depth, whereas her ideas of shape were completely obliterated, so that her tactual manipulations did not differ from those of other congenitally blind cases.

The patient in RAEHLMANN I [46] was nineteen years old, intelligent,

and apparently better equipped visually than Raehlmann supposed, as can be seen from the results of his pre-operative examination. Raehlmann expressly sought to employ this case to establish the difference between tactual and visual space; but apart from determining the patient's visual capacities before operation he undertook no tests which could have thrown light upon the particular conditions of his supposed tactual space. And these optical tests show that before operation his patient had made no use of his sight and had not arrived, even visually, at any awareness of space: for whether the light-source was shown openly or shaded, at one or ten inches distance, was of no significance for his process of recognition; his judgement was based only on a purely schematic distinction between contrasts of brilliance in relation to the general brightness within his field. Even after the operation he obviously had no notion that there was any such thing as extension in depth to the visual field. From the passage already cited above (p. 34) it seems that even Raehlmann did not suppose that his pre-operative visual performance would have sufficed to give him an idea of visual space. And this patient also had pre-operative nystagmus with uncoordinated eye-movements. In RAEHLMANN III [48], which also falls into this group, nothing definite was established about the patient's awareness of space. At nine years old the girl had gone deaf and gradually became dumb; at ten she became blind, and before the operation had become completely apathetic. After the success of the operation, speech and complete mental vigour were very quickly restored. The scanty indications of her behaviour in her newly recovered space of sight suggest that visual ideas had already been completely obliterated.

SCHNABEL I [33] had no nystagmus, his eye-movements being coordinated, though not under voluntary control. His occasional attempts to follow a light-source seem to have been equally set off by reflex action, since after the operation he could not achieve this at will. Schnabel mentions his ability to blow out matches struck in his neighbourhood, but even this seems to have been more or less of a party trick, having nothing to do with vision in depth. For apart from this accomplishment, spatial concepts of any sort were entirely lacking.

> Wishing, as he said, to look at [a toy, he often brought it] so close to his eye that it rested on the bridge of his nose and his eyebrow; the eye in question squinting strongly inwards, and the other strongly outwards.

Here the boy seems, rather, to have been playing at seeing, and perhaps attaining some sort of visual impression at the extreme edge of the temporal field. Schnabel's account suggests as much:

> He said of everything that he did not hold in his hand that it lay 'to the side'; he knew no other indication of place.

But subjectively speaking, even these words seem to be no indication of place, but may well have been used by someone on some occasion to refer to these sidelong visual impressions, and been picked up by the patient and endowed with a different meaning.

SCHNABEL'S second case [34], a twelve-year-old girl, is very similar to that of Fischer. She too, despite having seen until she was six, had virtually no remaining ideas of spatial shape. From Schnabel's account it is impossible to say whether she still had any awareness of spatial depth. For present purposes, therefore, we cannot take this case into account either; but both of them have their significance, since they confirm Ahlmann's statement that the onset of blindness leads to a gradual loss of all spatial ideas.

AUGSTEIN'S case [64] also belongs to this category of patients capable of perceiving direction and colour, but provides no details sufficient for an analysis of the spatial data available prior to operation. However, the patient's nystagmus, his clumsiness in moving about while blind, and his slow progress after operation in accustoming himself to spatial relations in the visual field, allow us to infer that even the conceptual space-schema of this fifteen-year-old boy was still quite undeveloped.

MINER'S case [59] may also be formally assigned to this class, but his account as a whole is equally devoid of evidence as to the patient's awareness of space before the operation.

Of the remaining cases that probably belong here – those of Janin, Albertotti, Trinchinetti (2) and Vurpas-Eggli (2) – we have already shown several times previously that the patients concerned had no pre-operative awareness of space.

If we now take a further look at the results in this group as a whole, it can be seen that presence of the physiological conditions for perception of direction and colour does not necessarily give rise to a visual awareness of space. For if we disregard the four non-assessable cases of Ware II, Fischer, Schnabel II and Miner, we are still left with thirteen cases in this group, of which only three, Ware I and Home I and II, suggest an optically acquired awareness of space prior to operation.

3. Brightness, Colour and Shape

Instances of this type include the three cases of Fialla IV, Francke and Raehlmann II, who *besides* having visual awareness of *direction and colour, could also perceive shape.* FIALLA IV [30] had a small translucent diaphragmatic opening in the lens-capsule of the left eye, so that he could see enough, albeit with great difficulty, to be capable of employment in a menial capacity.

> With the left eye he sees better at a distance; he holds objects at a distance from his eye in order to see them better.

He therefore evidently had a limited notion of shape. Of RAEHLMANN II [47], we are told, prior to operation:

> When food is set before her, she first looks at the object as closely as possible, keeping her head on one side and holding the bread, etc., close to her right eye.

So long as she fixated with one eye in this manner, the nystagmus ceased and both eyes moved in complete association. But

> when the patient sits unnoticed by herself she clearly has no visual sensations whatever; the eyes wander hither and thither in great convulsive leaps.

Even after operation the same thing happened at first:

> This certainty of ocular movement on fixation only occurs when, and so long as, the right eye participates in the process. If the right eye is closed during binocular fixation and she is asked to focus with the left (the weak-sighted eye), the same involuntary eye-movements occur as already described.

Thus here too it is again apparent that the ability to see is dependent, not only on the physical capacity, but on the desire to do so. This case resembles that of Schnabel I, except that here there were greater practical opportunities for employing the small remnant of vision and they were also used to greater effect. Moreover, despite her wholly eccentric manner of fixation, this fourteen-year-old patient of Raehlmann's could attain to no idea of the total form and shape of objects, since she could only see small portions very indistinctly; but as regards spatial depth she had thereby arrived none the less at a definite awareness of space; the spatial depth acquired by eye had enabled her tactual perceptions to

become picturable in a spatial fashion. Raehlmann says of her, shortly after the operation:

> The visual tests show that the patient is in full possession of spatial ideas; even before the operation, with her limited powers of vision, she had learnt so much about the space accessible to her touch, that she described a sphere held before her as a large yellow turnip. She also recognized correctly a round disc of similar cross-section to the sphere.

Thus, with the aid of small visible objects she had already obtained visual ideas of the basic forms.

And yet here too the above-mentioned example of the dog (p. 45) shows that the transference of visual ideas of shape to the tactual perceptions of objects did not lead to a tactual idea of shape in the mind of this patient. Only what she could grasp in full by successive visual inspections became picturable to her as a total shape; if, however, she could only see individual parts, these partial impressions did not suffice to aid her in uniting the remaining tactual impressions into a whole of this type; at best there remained an imaginary visualization.

FRANCKE'S twenty-six-year-old patient [50] could also fixate objects for a short time, estimate visual distances, distinguish objects by size and compare the lengths of their edges; he had deliberately sought to relate visual and tactual impressions together and to visualize his tactual impressions; but was somewhat handicapped in evaluating his visual data by *strabismus divergens*. The drawings he executed during Francke's pre-operative testing show how limited his notions of shape had remained, despite the aid of sight. They give very much the impression of purely blind drawings, which are guided entirely by the muscular sensations felt in following out the appropriate tactual sequence, and not by ideas of shape at all. Thus, after operation, he failed, for example, to recognize a pair of scissors, simply because he had drawn it pre-operatively in this fashion, and not as a shape.

These two latter cases also show that one is not entitled to attribute spatial shape to tactile perceptions. For when, given even a modest ability to apprehend shape by eye, we still find that everything perceivable not by sight, but by touch alone, remains incapable of being pictured as a shape, this shows that there is no such thing as tactual shape, that the two sense-fields have basically nothing in common and hence that they cannot replace one another in respect of their functions. It should be particularly noted in this connection that Francke's patient had had ten years of first-rate blind-school training in Stettin, and, in Francke's opinion, with excellent results.

All in all, therefore, of the many cases having limited powers of vision prior to the operation, we can find only six in which the patients had been able, by the help of these powers to arrive at an awareness of space; and this they owed entirely to their small stock of visual impressions and not to earlier tactile perception, so that it can only be described as a visual and not as a tactile awareness of space.

If we now ask how these six cases differed from the rest, and what it was that enabled them to arrive at this awareness, the reason must be sought in the fact that these patients had consciously endeavoured to make use of their limited powers of vision. For them the fixation of an object was no longer, as with Hirschberg and Raehlmann I, a casually occurring reflex-activity, occasioned, for example, by fright, but had become a conscious act, reproducible at will; and the success of their efforts to practise seeing deliberately is evidenced by their having already been able to some extent to overcome their nystagmus before the operation, whereas the other cases were only gradually able to achieve this after operation.

However small the practical advantages derived from their limited powers of vision, the fact that they were consciously employing this sense presupposes that its special nature has already been grasped in principle, and that they now have a vital interest in making full use of their visual impressions and fitting them into their previous system of ideas. The first thing obtained thereby is an awareness that things are spatially remote from us, and that the other senses are no less capable than the eye of grasping and perceiving objects separated from us in space. What had previously been apprehended only in connection with the patient's own body, and to some extent as belonging to him, is now gradually located in space outside this body and related thereto. The notions of shape undergo a less definite alteration, since the tactual impressions only acquire the property of shape when they can be backed up by visual memories. But once the basic forms can be grasped as such (i.e. as shapes) from experience of small visual objects, what had previously been a lifeless, shapeless schema also acquires a certain shapeliness of structure, albeit subject to visual influences. Now as before, touch continues to be the main sense, but the mere unimaginable knowledge of an order of things in space comes to have a content that even the patient can understand. This can be recognized in the greater certainty of his demeanour in space, and in the considerably greater speed with which he learns to see after the operation, both in depth and in the apprehension of space, because basically they involve only a quantitative

extension of capacities already present, and one which no longer furnishes them with anything wholly new.

This is particularly clear in the case of WARE I [11]. Since the boy in question already had a notion of seeing and the visual field, he was no longer worried by it and himself took the initiative after the operation, in order to discover as soon as possible what real seeing meant. HOME II [14] did the same; whereas HOME I [13], who suffered from painful symptoms of inflammation, could not see at all for the first fortnight after operation and even later attained no adequate sharpness of vision. RAEHLMANN II [47] and FRANCKE [50], on the other hand, both showed in the pre-operative tests that they already knew what seeing was; and attempted by numerous inquiries to shorten the period of learning to see. What most of the other patients took months over, was the work of a few weeks for them. It should be particularly noted, moreover, of Francke's case, that his pre-operative visual capacities were weaker than in many of our other cases who failed to arrive at an awareness of space, but that he was probably the only one who had realized, by systematic use of a footrule, how to integrate the two fields in a useful way, so that even his tactual estimates of size were more reliable. For all that, we still find, even in this case, a tendency to order the visual data also in schematic relations; and his range of spatial ideas hardly extended beyond the field actually under his eyes.

But this case of Francke's leads us to the major factor whereby these six patients are distinguished from the remainder, and also gives us the main reason why the others, despite equally good physiological facilities for seeing, did not arrive at an awareness of space: it is their intelligence and will to live. In themselves their exiguous opportunities of seeing would hardly have sufficed to afford them awareness of the depth of space. But since they were accustomed to make use of everything, and had thereby already acquired extensive schematic notions of space, they also made use of their visual capacities and tried experiments on their own account, which informed them that the visual appearance of an object undergoes certain changes as it slowly recedes from the eye. This may indeed have been partly just a game at first, as with Ware and Home; but the important thing was that they thought about the impressions gathered from this game, and did not merely enjoy them as qualitative stimuli and accept them as such. In this respect Hirschberg's and von Hippel's cases were obviously in a transitional stage; they too would probably soon have come to the same realization; whereas in Latta's case the powers of vision were just not good enough.

But if, on the other hand, we consider cases like those of Janin, Albertotti, Vurpas-Eggli, Schnabel, etc., who stupidly let everything pass them by, did not want to think at all if they could help it, and preferred to vegetate thus within themselves, it emerges quite clearly from the above that it is not just a matter of the visual powers actually available, but of how they are employed; and whether they are employed depends on the personality of the individual. In spite of that, many others of our cases would certainly have succeeded in arriving at an awareness of space by visual methods if spatiality had not been for all of them something quite unsuspected by touch alone, and lying right outside the field of ideas created on that basis. Only so is it possible to understand how acquaintance with colours did not equally lead *all of them* to an awareness of space. Again the reason is just this, that the patient can get no knowledge of space from his tactile experiences that could serve him as a basis for similar experiments with his scanty remnants of vision.

But this also makes it intelligible how the spatial field that the patient is able to 'see' after his operation depends, not only on the objective potentialities of vision conferred by the operation, but also in large part on the extent of the field of spatial ideas possessed beforehand. The seemingly remarkable fact that though operated patients generally localize visual objects at a certain still indefinite distance, they almost always underestimate such distances by a considerable margin, finds here a perfectly natural explanation; the fact being that the patients have absolutely no spatial concepts derived *a priori* from touch, and by thought alone can likewise bring to mind schematically only a narrowly restricted spatial field. Those who already possess a visual awareness of space before their operation naturally have a great advantage in this respect also over the remainder, who have been entirely dependent on their tactual experience.

III

SPATIAL DATA FROM HEARING

To ask whether or not there is an auditory space is equivalent to asking whether the hearing of a noise of unknown quality and intensity, where hearing alone is operative in complete isolation, conveys, in addition to the primary sensations of quality and intensity, a clear-cut awareness of spatiality as regards the direction and remoteness of the sound-source.

If, as sighted persons, we endeavour to discover exactly how we arrive at our judgements about the direction and distance of sounds, we shall have to admit that visual judgements are almost always involved. A sound strikes our ear and causes us to look in the approximate direction it appears to come from, and to seek out the source by eye. Since only a few objects are eligible to produce the quality of sound heard in each case, we generally discover the source at once, so that the whole process appears to us to merge into one. We have obtained the exact direction and distance by eye, but are convinced of having already got both from the auditory impression alone. We find a very typical example of this in HOME II [14]:

> Next day he told me he had seen 'the soldiers with their fifes and pretty things'. The guards in the morning had marched past the hospital with their band; on hearing the music, he had got out of bed and gone to the window to look at them. Seeing the bright barrels of muskets, he must in his mind have connected them with the sounds which he heard, and mistaken them for musical instruments.

Thus the boy was looking for the sound-source in the wrong direction, caught sight of the muskets in this direction, related the two together, and so now localized the music in the wrong direction also, since he did not know the visual appearance of the instruments. If he had known them, he would simply have looked along the column until he had found them.

Our judgements about visual impressions are no less strongly affected by the auditory and other impressions that invariably accompany them.

Now in the congenitally blind the whole visual sphere is inoperative,

so that in determining the position of a sound they have no such aid from vision. It therefore seems advisable for us to examine our material on this point also, to determine whether the patient's auditory impressions have an *a priori* spatial character, whether they give him awareness of spatiality in the absence of any intellectually acquired knowledge of relations, or whether he originally distinguishes these impressions by quality alone and only gradually learns – as his empirical knowledge increases – to employ them for purposes of orientation; in so far as he discovers how to transpose the variety of given intensities of a known sound into approximate estimates of its distance.

In this connection we can neglect the influence of any pre-operatively acquired space of sight, since none of our cases were able, at that stage, to recognize a sound-source by eye.

Since the details relating to the use of auditory impressions are somewhat scanty and cannot be sharply separated as to their bearing upon 'direction' and 'distance', we may take them and analyse them in order. The first to be considered is LATTA I [60], of whom it is said:

> His hearing was so acute that he knew at once if there was anything unusual on the road along which he was walking, and thus he never had any difficulty in keeping himself out of danger.

To the sighted person this sounds at first as if the patient must have had some sort of idea of the street stretching out ahead of and behind him, and must have associated every noise with a spatial idea of the greater or less distance of its source. Latta himself seems to have thought otherwise, when he subsequently remarks that in walking the street his patient knew only how to make use of the qualitative differences among his auditory impressions. Here too there was a sort of schema: he knew that the sharp echoing of his steps meant that he was going along by a wall; a 'hollow' sound told him that he had reached a gateway or a gap in the houses; a third nuance of sound indicated a hedge, and so forth. He likewise knew the ring of a well-fixed horseshoe from that of a loose one, indeed he could even dream of this difference.

> In a strange place, however, he could never trust himself to go about without a guide, because his sense of hearing conveyed nothing to him beyond the difference between passing buildings or open spaces. . . .

Since, in his native village, the great majority of the houses were detached, the young man was able

> to count the houses as he passed, and thus to turn corners and finally stop at the one he wanted.

This case therefore shows clearly that the blind patient also incorporates acoustical impressions into his environmental schema. The central point of this schema was the shop he worked for. In setting out from this point (whether or not, on leaving the door, he turned his body to right or left and went along the house-fronts, or crossed 'straight over' the street without turning) he knew, in every direction that mattered to him, the permanent sequence of changes in his auditory impressions as between the larger individual units (crossings, corners, etc.), and remembered by heart both their number and significance (name of the owner, etc.). By means of this ever-reliable schema of auditory impressions, recurring always in purely temporal sequence, he was conveniently able to achieve orientation. But as soon as the schema was left behind this imposing power of orientation also came to an end.

This is the only construction that can be put on the details furnished by Latta, and it may well have been also what he himself had in mind. But once we have clearly grasped the significance of such a schema, built up in succession, and experienced, not spatially, but in purely qualitative fashion, we shall also be inclined to interpret the first passage, about particular happenings in the street, on similar lines; namely that the patient's ability to avoid danger was likewise a matter only of schematic knowledge, without any immediate spatial impression; that on hearing a cart coming, for example, he had no spatial awareness of a gradual and continuous change of location, but was concerned merely with a piece of empirical knowledge: the familiar sound of rolling wheels spells danger; he knows he is safe on the pavement, and so simply stands still; the intensity of the sound gradually increases, and its maximum is the high-point of danger; he knows that when it begins to fall off again he can go on his way. We naturally presuppose here a repeated acquaintance with the whole scale of intensity, e.g. of a passing cart. Since his first ventures on the streets were made with a companion, he will also have had indications on what to do. Latta unfortunately gives no further details as to how his patient behaved in moments of danger, or whether when on the move he was also invariably orientated as to where the danger lay; but we may well assume that so long as he was on familiar territory he had already advanced beyond the initial stages, in virtue of increasing confidence and experience.

When it is further said of him:

> He was also employed to feed cattle and was guided to their stalls by hearing,

we also have, just as before, an integration of auditory impressions with

the environmental schema. The 'directions' involved in the work of the household were known to him, so that he would have found his way to the cowshed even without the noises made by the animals, and these will therefore have been more in the nature of guiding cues to assist him.

This is just what happens even in our own case, as sighted persons: we also have a sort of situational plan continually in mind, and the knowledge of the field that is alone relevant to a particular noise guides our attention in a specific direction, which we then suppose to have been given by hearing. And so too, in virtue of his tactual schema of the environment, Latta's patient also knew at any moment, when on his way to the cowshed, for example, where he was, and that any lowing of cattle could only come from the 'cowshed' familiar to him; these animal sounds therefore functioned for him as a sort of confirmation of his intention to go to the shed. At all events, there is no reason to suppose that he had a positive qualitative experience of the direction of sound.

NUNNELEY [21], whose patient had been brought up in equally rural surroundings, gives a similar account of the avoidance of danger-sources intimated by ear:

> Walking along the middle of the road, when he heard any object approaching, he at once stopped, groped his way to the side of the road, and remained perfectly still until it had passed.

Here too, therefore, we find the same schematic type of behaviour: normally the boy will have wanted as much 'room' as possible on either side, to move unimpeded by obstacles, so as not to have to exercise continuous tactual control. But when a noise comes along, the other schema takes over, and here the only thing used is the rise and fall of the sound, without the boy seeming to have any awareness of the object's steady change of distance and direction.

MINER [59] tested his woman patient, among other things, for auditory range and discrimination, and found approximately normal values for intensity, together with increased range.

> Her localization ability was tested by Mr Starch with the Seashore sound perimeter. The most noticeable factor here was an inordinate tendency to move her head in order to localize the sound.

But here again Miner gives no exact figures, so that not much can be made of this information. The behaviour of the patient is, however, very like that already described (p. 90) of the blind when determining the direction of a light-source. The exploratory turning of the head in fixing the direction of sound shows that here also we are dealing with

an indirect, mechanical procedure: she did not perceive direction in hearing the sound itself, but helped herself by trying to discover the position of the head in which both ears received the sound at equal strength; she therefore turned her head to and fro a number of times, and eventually found an intermediate position where she thought she had an impression of equal sound-intensity, and then had the direction immediately 'in front' of her. What she was aligning here was a sensation in her own ears and not the direction of a sound given to consciousness as somewhere in space. She knew only that every noise proceeded from a source situated at some undefined 'distance', and this knowledge has become so much a fixed assumption in many blind people that they themselves believe they hear the noise as located 'outside' them.

UHTHOFF also gives some account of the manner in which his patients made use of their auditory impressions. In the case of the three-and-a-half-year-old girl with temporary amaurosis [55], he says, of the first visual test:

> On being called to come, the child at first stands still; only when bidden more firmly does she begin to grope slowly forward, obviously directing herself by ear alone, though her eyes are wide open. Her line of advance is generally a wrong one, and she bumps into every obstacle.

And later:

> If a piece of sugar, which the child has a liking for, is thrown on the floor in front of her, so that she hears where it falls, she still does not look down at all, but gazes aimlessly straight ahead.

But then gradually this coordination between sight and hearing is built up: on the fiftieth day of observation

> it can be established as a new fact, that when the child is called she occasionally turns her eyes towards the caller; and already, when she hears something fall on the floor in front of her, she glances to and fro purposefully in order to pick it up.

It should be noted in this case that the child had only been blind for six months, albeit at the age of three; in spite of that, virtually no memory-images appear to have been preserved over this short period. Here, quite plainly, we have the gradual development of mutual coordination between auditory and visual impressions. At first the auditory impression means nothing to her; it only acquires significance through the finding of an object and the recollection that this finding was preceded by an auditory impression. Similarly, she knows that the hearing of a voice can only emanate from some person or other. Thus

when she now hears words spoken or an object falling, she knows which field is in question as the source of the noise; her visual searching is thereby restricted in advance.

In his next case also [56], Uhthoff only made auditory tests after the operation, in conjunction with visual ones:

> When the patient was asked, at this period, to close his eyes and point in the direction of a sound-impression, he could do it relatively well; but it later emerged clearly how he gained in confidence when he was able to control the pointing of his hand by eye, and could thus both see and hear the person calling him.

He also tested the totally blind woman of thirty-seven [57], who was not operated on:

> The patient's estimation of distance by ear is decidedly uncertain. She seems indeed to have had little practice in this respect, for instance in counting off the steps, a practice to which the pastor has long since directed her attention as an aid to orientation. She can point quite accurately to the direction a sound is coming from.

Of his first case [45], the seven-year-old boy, Uhthoff says:

> At first he also seemed practically incapable of pointing correctly in the direction of a sound with his outstretched arm. In the later period of visual testing he has gradually learnt to point out quite quickly by hand the direction in which he sees or hears anything.

These passages again confirm that sound localization by itself, without the aid of other senses, is only very indefinite; it is visual control that first makes greater certainty possible, because one then sees in the approximate direction only a small selection of objects, whose visual image is eligible to fill out the sound-impression. This leads one to overestimate the exactness of direction given by ear. Uhthoff unfortunately gives no exact values for these experiments, doubtless because the phenomena reported were merely unintended side-effects of his visual tests. It would probably have made a great deal of difference, also, whether or not the subject had already acquired a tactual space-schema of the testing-area. For if the patient has that, he also has a clue to the possibilities of coordination that might be relevant to a noise (position of the door, window, etc.).

The sighted, too, are equally inaccurate in their estimates of direction, once the sound-sources are concealed. Even when the potential region of emission is narrowed to a sector of about 40° from the subject, individual estimates vary up to 20° on either side. This ability to tell the direction of a sound by ear can be greatly improved by practice, though

all that happens with the blind patient is that his auditory impressions are fitted into a directional schema obtained by touch. Thus DIDEROT says:

> Our blind man points with such exactness at the place whence a noise comes that I make no doubt the blind may, by practice, become very dexterous and very dangerous. I will tell you a story which will convince you how imprudent it would be to stand the throwing of a stone or discharging of a pistol by a blind man. . . . He had in his youth a quarrel with one of his brothers . . . seized the first missile which came to hand, threw it at him, and hit him directly on the forehead, so as to lay him flat on the ground.

But his success here should not be put down simply to his accurate sense of auditory direction; it is based on the exact situational awareness that this patient must have had within his long-familiar living-room. Thanks to the position of the furniture, etc., he was well aware of the main relevant 'directions' (again to be understood here in a dynamic sense, and so too, in what follows, with words like 'place', 'side', etc.); moreover, the direction would naturally be rendered even more exact by the constantly renewed auditory impressions arising in the course of an altercation; the two contestants, guided by a whole series of auxiliary impressions, will have quite spontaneously stationed themselves face to face, so that when the blind man lost his temper he will only have needed to throw more or less 'forwards', in order to score a hit.

This already brings us to the end of such data as can be gathered on the problem of spatial hearing. They relate exclusively to the determination of direction from a given sound, there being no information as to whether the blind also arrive, from the auditory impression alone, at an awareness of the remoteness of the sound-source. We might possibly cite the passage in ALBERTOTTI [39], where he wanted to stand with his protégé on the front platform of a horse-tram.

> He does not dare to hold on to the front rail, because he hears the sound of the horses' hooves too close to him, and is afraid they will pull off his hands.

Here too, however, it is obviously only the intensity of the noise that frightens him, coupled with the knowledge that the animals are immediately in front of the vehicle.

So far as we are now entitled to draw any general conclusions about auditory space-perception from this scanty evidence, it seems fair to say that hearing, in and by itself, conveys no impression of direction which can claim to be in any way exact. What the blind man can discover on his

own, with some accuracy, is initially little more than an impression that his auditory sensations are stronger in one ear than the other, and hence that the sound-source must lie on the (tactual) 'side' where it is heard loudest; and he can thereupon make use of special learned habits to fix the 'direction' somewhat more exactly, by determining the position of his head at which the sound-intensity is at its height. Given a momentary noise, however, he will not be able to fix its 'direction', unless helped by knowledge of the objective location of his body in relation to things in the environment. In ordinary life it is not so difficult for the blind man to direct himself by auditory impressions, because he always knows, within his framework of order, the relations of his present 'position' to the environment – what is already behind him, what is still to come, which 'side' the roadway is, which side the houses, and so forth; he therefore also knows quite accurately on which 'side' to expect auditory data, and pays particular attention to this side, so that basically he only has to determine whether a noise is in front of him or behind him. For motor reactions to these data it is quite sufficient for him to know in which of the four main quadrants the noise is situated; more than this he does not in fact discover, and even so there is already a great deal of knowledge involved.

If the above-cited passages already tend to show that the auditory impressions of the blind have little that is spatial about them, it is still more evident from the other particulars in our material that the main value of hearing to the blind man lies in the qualitative differences between his various auditory impressions; it is *these* that enable him to recognize the nature of the sound-source, and they are also the only means he has, for example, of forming judgements, from the sound of their voices, about the individuality of his fellow-men. This consideration only arises, of course, for those patients who are in general anxious to make closer contact with their fellows, and are not just living from day to day in a purely vegetative fashion.

GRANT'S twenty-year-old patient [4] was betrothed to a lady who, being somewhat ill-favoured by Nature, had expressed her anxiety lest he should cease to love her when he could see. Before she herself removed the bandage from his eyes he made her the following declaration:

> Dear Lydia, If I am to lose by sight the soft pantings which I have always felt when I heard your voice; if I am no more to distinguish the step of her I love when she approaches me, but to change that sweet and frequent pleasure for such an amazement as I knew the little time

I lately saw; or if I am to have anything besides, which may take from me the sense I have of what appeared most pleasing to me at that time (which apparition it seems was you): Pull out these eyes, before they lead me to be ungrateful to you, or undo myself. I wished for them but to see you; pull them out, if they are to make me forget you.

DIDEROT [6] says of his blind man:

He has a surprising memory for sounds, and can distinguish as many differences in voices as we can in faces. He finds in these an infinite number of delicate gradations which escape us because we have not the same interest in observing them. . . . The mutual aid our senses lend stands in the way of their perfection.

Of LATTA I [60] we read:

He recognized the presence of strangers in the house chiefly by the sense of hearing – for example, he could discriminate persons whom he knew by the sound of their respiration, and he was at once cognisant of any breathing with which he was unfamiliar.

NUNNELEY [21] says:

Any one whom he knew, he was able to recognize by the sound of the voice. . . .

UHTHOFF'S thirty-seven-year-old patient [57] is thus described:

In remembering persons and certain animals she is primarily guided by her auditory memory-images. . . . She remembers the voices of people in their absence. . . . Thus she remembers her mother chiefly by her voice.

GRAFÉ [49] writes similarly of his fifteen-year-old patient, when visited by his mother some six weeks after the operation.

He turned his gaze towards the new apparition, picked out something that he recognized as a woman, and then carried on as before. But as soon as the mother let him hear the sound of her voice, which he knew, the boy flung himself upon her.

FIALLA writes of his third case [29]:

that he could no longer recognize his old friends until he had heard their voices.

Finally, it is said of the GETAZ case [65]:

Faces are so bewildering to Joan that she still judges people by their voices. . . . Whether smiles are sincere she determines by the smiler's voice.

What all these statements show is that individual peculiarities of voice are the really important thing to the blind man, since he has no

other way of analysing a spontaneous expression of self on the part of his fellow-men, in order to perceive their character and to conduct himself towards them on the strength of the impression so gained. He already knows, from the given situation, where the person he is talking to is actually located, and so where to direct his voice.

Now there might also be a certain space-effect derived from the fact that, in touching objects, the blind also become familiar with the typical noises that can thereby be elicited from them; so that they would acquire an awareness of the spatial remoteness of these objects when they again heard this typical noise without finding the object itself within arm's reach. But in all the examples telling on this point it is invariably a question of recognizing the sound-source as the object itself, without there appearing to be any interest in knowing how far away it is situated.

Such examples are naturally very numerous, since they play a large part in the post-operative visual tests, where such unintended ancillary sounds, often unnoticed by the tester himself, enable the patient to identify objects that he cannot pick out by eye. Thus GRAFÉ [49] gives the following example:

> When the Lady Superior showed him the large rosary that she always kept hanging at her girdle, and asked him what it was, he immediately replied: 'That's a rosary.' When she seemed surprised that he could name an object so exactly on seeing it for the first time, he added that the noise made by the object when it was held out to him had reminded him of a noise to which his ear was accustomed, and which had long been associated, through other rosaries, with sensations of touch and manipulation.

The lack of a constituent notion of space is equally evident in those passages which disclose the cognitive value of auditory impressions to the blind in practical life, and the procedure by which they make use of them. Thus DIDEROT'S blind man [6], in bottling the liqueur that he manufactured, controlled the fullness of his flasks by the sound of the vessels and the continually rising note given out as they filled up.

VON HIPPEL [23] writes of his four-year-old girl patient:

> When I asked her to touch a glass one day, and she could not at first recognize it, she tapped on it with a finger and immediately named it correctly from the ringing sound; she did the same with a taper-holder, describing it from the sound of the metal as a money-box.

SCHNABEL'S five-year-old boy [33] was able to recognize the whole

progress of a procession going up the street, in all its details, by auditory impressions alone.

VURPAS-EGGLI'S boy [52], also a five-year-old, is just like other children:

> When he is asked how the horse is, he imitates its neighing; so too with the railway, he mimics the sound of the train. After visiting a menagerie he seems likewise to have retained only auditory recollections. Asked how the lions are, he imitates them roaring.

Here, therefore, the various noises made by things and animals form the significant content of the verbal signs in question; they provide the intellectual contact with such objects as are inaccessible to the patient's touch.

Even WARDROP'S deaf-blind boy [15] still made use of the exiguous auditory impressions (the inner ear being not entirely destroyed, apparently), which reached his inner ear from the mouth through the bones of the skull; they served as a source of knowledge, in that he rattled various suitable objects to and fro between his teeth in order to discover thereby what the object was made of (wood, metal, stone, etc.).

These examples could be multiplied indefinitely from behaviour during visual tests. But once again they all serve to show only that the blind man's auditory impressions are attended to initially in respect of their quality alone, that they provide a valuable aid to his sense of touch, and hence that they furnish extremely important constituents in the build-up of his system of knowledge about the things in his environment. There is, however, not a single passage in our material suggesting that the impression of spatial remoteness is also given to the mind along with impressions of hearing.

It seems doubtful, therefore, whether auditory impressions are accompanied *a priori* in the mind of the hearer by an impression of depth. Their so-called spatial character would seem to be acquired only by the fact that the blind man seeks to relate his auditory impressions to the environmental schema he has built up.

progress of a procession going up the street, [illegible] alley, [illegible] departs [illegible] along.

[illegible] in a [illegible] also in [illegible] understood [illegible]

When he is asked how the [illegible] he [illegible] in [illegible] the railway [illegible] of the [illegible] the agents [illegible] only [illegible] the [illegible] he [illegible] their [illegible]

[illegible], therefore, the various noises made by things and animals [illegible] the [illegible] of the [illegible] in question, they provide the intellectual contact with [illegible] are inaccessible to the [illegible] touch.

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PART II

The Attainment of Visual Space after the Operation

In analysing the spatial possibilities available to the patient before operation, through touch and hearing, we have been moving in a field that has lain throughout in the background of interest of those who have furnished details of our cases. In most instances the period of observation before the operation was only a short one, and served the surgeon only to decide upon the method of carrying it out. His main interest was naturally in the operation itself, and in the subsequent period of learning to see, which had formed the centre of scientific interest because of the controversies surrounding the visual perception of space. In so far as no systematic tests were instituted, the numerous reports about the spatial possibilities available prior to operation were therefore in the nature of casual observations.

In analysing these statements about tactual space, we have already made a short digression into the field of vision. There it was a question of deciding, given the meagre powers of vision of cataract patients, where to draw the line as to the possibility of speaking of a conscious employment of visual impressions – at what stage it could be said that the patient was already sighted before the operation. Our conclusion has been that the overcoming of nystagmus, due to frequent and deliberate practice in fixating particular light-sources, should be the criterion by which to decide whether the individual patient, in virtue of the spatiality of his impressions, should still be assigned to the tactual sphere of the congenitally blind, or already to the visual sphere of the sighted. The six cases which we have already reckoned, prior to operation, among the sighted, exhibit a clear contrast to the remainder. Their peculiarity lies particularly in this, that by means of this conscious use of all visual possibilities they had to some extent gained access to the sphere of the sighted, and had thereby also acquired an awareness of the spatial depth of visual space; a consciousness of space which they

had not previously possessed from touch, and which the other cataract patients had not achieved, even though their powers of vision were by no means wholly deficient.

It may perhaps be objected here, that this strict division into two separate spheres is not justified, since it cannot even be applied to the normally sighted person; seeing that in his case touch and sight are called on to cooperate throughout, in mutual supplementation, to apprise him of space, and serve as coordinated organs for this purpose. To be sure, it is often alleged of the growing child that touch plays a dominant part in regard to his apprehension of space. But this assumption is not confirmed by the experiences of our patients. For in many cases, and most clearly in Dufour, Uhthoff and Ahlström, the exact moment can be given at which the toucher became a seer, at which orientation by touch was dropped in favour of orientation by sight. Whereas at the beginning sight has only an auxiliary function, at a particular stage of development the relationship is reversed, so that from then on touch, apart from qualitative impressions, which are also important to the normally sighted, for the most part fulfils only a supplementary role, in order, for example, to facilitate the contemplation of objects in the round.

The child that is normally sighted from birth possesses in advance an ability to see which the operated patient often acquires only a considerable time after the operation; and in his many and varied manipulations of objects he is obviously no more concerned than the adult (or the patient who has reached this stage) with orientating himself in his spatial relationships with things. At all events, I see no sufficient reason for crediting touch, in this fashion, with the function of forming spatial ideas. These very six cases, who were already consciously using their remnant of vision before the operation, show clearly – as they also do later when their vision had further improved – that they must be sharply distinguished from the other cases, who could *only* make use of touch.

Now from this fact, that only a few of our cataract cases were able, through laboriously conducted trials and experiments, to arrive at a visual awareness of space, one might be inclined to conclude that this was itself already proof of the fact that, as pure sensations, visual impressions have no *a priori* spatial character; because otherwise the visual impressions of *all* our cases must have been spatial. But this would be a fallacy, since in none of the six cases can one speak of normal vision. On the contrary, they are simply using a less opaque patch, happening to lie in some peripheral part of the lens, which does indeed

leave open a minute segment of the visual field, but only allows the light-rays to enter at a point outside the *fovea*, so that at best only a completely vague, diffused visual impression can occur. It is just like looking through a sheet of milky glass, and hence, even in these six cases, cannot have led to more than a preliminary intellectual interpretation of the visual impressions so obtained. The notions of visual depth acquired will have been obtained indirectly from the change in brightness or colour on the approach of a coloured object; of shape itself they saw nothing. Yet even so, their mode of touch had also acquired something spatial in the process, and they therefore already entered the post-operative tests with an awareness of space.

On the statements made by our patients, in response to their first visual impressions after operation, a whole mass of theories has been erected and obstinately defended, centring upon the question, how space is presented to man through sight.

In making use of such statements, one must be clear in advance that the utterances of patients on gaining their sight are a great deal more difficult to analyse than those made before operation, while they were still blind. Prior to operation, the congenitally blind person is on familiar territory, and the doctor or psychologist cannot follow him into all the recesses of his thinking and imagining, although during the tests he is visually orientated throughout as to what is objectively presented to his patient, and can also follow the latter's behaviour by eye in the course of the test. The patient himself, so far as he is not intellectually retarded, is at least perfectly clear, before the operation, as to his subjective experiences; and expresses himself clearly, albeit in a language that he has borrowed from the sighted, and has in large part endowed, in accordance with the divergent forms of his ideas, with somewhat different meanings. And the observer now has the task of comparing these subjective utterances with the objective behaviour of his subject, in order thereby to get at the real content of what he has to say.

Now after the operation, it is the observer who seems to be on more familiar ground, so that one might think it possible to obtain a more reliable interpretation of utterances relating to vision. But in reality the observer knows just as little, after the operation, as to how the patient may be experiencing the visual, as he does before operation about the deliverances of touch.

The patient, on the other hand, once relieved of his cataract, finds himself thrust into a highly uncongenial situation, in so far as everything,

for him, is now a *terra incognita*. Whereas, before operation, one could at least trust the subjective correctness of his assertions, so that the task consisted only of interpreting them correctly in terms of the mental life of the blind, his post-operative observations involve many other elements of uncertainty. Even after operation, there need be no doubt of his subjective conviction of the correctness of what he says, so long as he generally enjoys learning to see; but the patient's mental powers of imagery, his forms of thought and his capacities for linguistic expression are still completely rooted in the old sphere. Apart, therefore, from the fact that he is himself not completely clear about his own impressions, he is also compelled to clothe them in a language which he has hitherto employed only for his experiences as a blind person, without spatial data. Objectively speaking, therefore, his remarks bear throughout the imprint of the fact that, having gained his sight, the patient is still trapped in a sphere he has not yet transcended, and which, as previously shown, offers him no immediate points of contact whatever for the new visual sphere. In these visual tests, indeed, it becomes especially manifest that although both parties – the observer and the subject – speak the same language, they attach different concepts to a great many words; so that this alone is enough to create misunderstandings on both sides, which can only be avoided by the doctor or psychologist making himself thoroughly familiar in advance with the mental habits of the blind. This necessity became particularly clear to MOREAU, for example [63], as the result of his experiences with his patient:

> One must first spend some time in getting used to employing an appropriate mode of expression. One too readily forgets that one is a sighted person. One has to work out one's own mode of expression, and this calls for considerable care.

In evaluating the utterances of patients in the course of their first trials, the chief thing to be wary of is that at this point they are for the most part still under certain mental and physical influences, which later disappear. The operation is always accompanied by some degree of mental shock, even in virtue of the knowledge that the patient is confronted with a turning-point in his life. In the early trials, moreover, the pain caused by the unaccustomed exposure to light has often not yet subsided; such factors naturally stand, for the patient, in the forefront of his attention; and this particular direction of his attention has as its result that he construes many questions wrongly, and relates them to things that are in fact the object of his own preoccupations.

Moreover, at the time of the first visual trials, it has generally not

been possible to determine the objective powers of vision, so that it has also not always been established with certainty whether after-effects of the operation were not present, which must have had a greater or less effect in altering the objectively given, as it appeared to the patient.

It is therefore a question, in each individual case, of following out the particular circumstances of the actual visual trials, thinking oneself into the mental habits of the patient, and from thence undertaking a critical analysis of whatever verbal formulation he gives to his impressions, in order thus to arrive at the objective content to be attributed to what he has to say. For purposes of objective appraisal, particular value attaches to the statements of those patients who were already prepared to some extent for their task before the operation, received adequate intellectual training, and were sufficiently conversant with the usage of words, to be able themselves to become clear about their own impressions and to give them intelligible verbal expression; those, in short, who were relatively well-qualified for psychological self-observation in the course of these visual tests.

I

THE VISUAL PERCEPTION OF SHAPE. INITIAL BEHAVIOUR

In analysing the first visual experiences of the patient after operation, we shall not apply ourselves immediately to the problem of vision in depth, but shall first notice how the patient conducts himself towards the shape-aspect of visual objects; and shall follow out the process of development which, given reasonably favourable powers of vision, gradually leads to a grasp of shape. This seems advisable, because the interest of the newly operated patient is quite exclusively directed, at first, to the recognition of visual objects. Moreover, if we were to anticipate the treatment of vision in depth, it would soon appear that here already a great deal is essentially governed by the progress made in the apprehension of shape. We shall therefore leave the problem of vision in depth entirely on one side to begin with, though at the risk of some repetition later on in dealing with this question, owing to the further reference that will then become necessary to the first visual trials.

1. Absence of Transfer from 'Tactual Shapes'

We shall begin our examination of the process of acquiring visual ideas of things, as it relates to the problem of tactual shape, by asking whether that which the patient claims to possess as a spatial touch-'shape', and which many sighted persons are also ready to concede to him, in virtue of his manner of speaking and behaviour towards tactual objects, really has the character of shape, to the extent that the patient is able, after operation, to '*recognize again*' even a single visual *shape* by virtue of the 'tactual picture' that he is alleged to have formed on the strength of his tactual impressions.

To this it will probably be objected that such a demand would be unreasonable, in so far as the patient makes use of quite different impressions of things in forming his 'tactual shape', brings it about by

the aid of a different organ, and consequently acquires a 'shape-image' which, having no colour, can in no way be compared with a visual shape.

As was already observed by JANIN [8], in 1764:

> An object must make upon the visual organ proper an impression entirely differing from what is commonly supposed. One must not be deceived in this: what the mind is acquainted with by touch, it does not perceive by the use of a new sense.

To this we may remark that we ourselves have arrived, in the first part of this book, at the conclusion that the unalterably successive, tactile and dynamic mode of apprehension among the blind must inevitably lead to a different sort of apprehension of things. If it now emerges, in the process of learning to see, that all the spatial impressions given by sight present something utterly new and for long unintelligible to the patient, so that it becomes obvious that the terms 'space', 'shape', etc., have an entirely separate meaning for the blind, which cannot be in any way reconciled with normal verbal usage, one ought therefore to avoid in principle the application of these spatial words to their tactual experience; seeing that visual space has always constituted the normal space governing the origin and gradual change of meaning of spatial words. But if, in spite of this, one is still inclined to apply spatial terms to the blind, because one jibs at the necessary rethinking in terms of their own mode of apprehension, one must at least be clear in one's own mind that these spatial words, for the blind, have nothing to do with the apprehension of space.

This is evident, indeed, from the fact that in their first attempts to see the patients cannot recognize by eye even the simplest structural shapes; though certain patients (e.g. those of Latta and Raehlmann I, and the Getaz case) had claimed, before operation, to have a perfectly clear spatial idea of them, derived from touch; shapes which they recognize every time by tactual control.

DAVIEL [7] was already quite categorical upon this point in 1762, on the strength of twenty-two congenital cataract patients on whom he had operated:

> I can assert, indeed, with absolute assurance, that not a single one of these patients has recognized the objects shown to him after the operation, without the use of touch, unless they have been many times shown to him and named. . . . If it has been said that some such patients can distinguish objects exactly and completely immediately after the operation, then this shows that they were not really blind from birth; for the latter have no real idea at all of even the meanest objects.

The case of HOME II [14] (*cf.* p. 77) is also very characteristic:

> The eye was allowed ten minutes to recover itself; a round piece of card, of a yellow colour, one inch in diameter, was then placed about six inches from it. He said immediately that it was yellow, and, on being asked its shape, said 'Let me touch it, and I will tell you.' Being told that he must not touch it, after looking for some time, he said it was round. A square blue card, nearly the same size, being put before him, he said it was blue and round. A triangular piece he also called round. The different colours of the objects placed before him he instantly decided on with great correctness, but he had no idea of their form.

Illustrations of this are so very numerous, and so widely distributed amongst almost all the cases, that they cannot all be adduced within the scope of this book. We must therefore confine ourselves to giving only a few particularly striking examples, and that chiefly from those cases in which the surgeon was confident of having established sufficient acuity of vision for the first visual tests. We shall then be the more ready to go on and analyse those passages which might superficially tend to create the impression that in these cases a visual recognition of shape was immediately present; and will illustrate our account by other passages, in which there is incontestable evidence of the aids whereby the patient arrived at his interpretation of the visual impression.

Let us therefore confine ourselves right away to the cases which were prepared for the visual trials, before the operation, by systematic tactual trials, and in the first post-operative visual tests were confronted with the same objects. We select these cases on purpose, because it might possibly be objected to the others, that the patients in question were so stupid and backward mentally, that such tests were already beyond their intellectual level.

Our first example, then, is from NUNNELEY'S case [21]:

> After keeping him in a dark room for a few days, until the opaque particles of lenses were nearly absorbed, and the eyes clear, the same objects, which had been carefully kept from him, were again presented to his notice. He could at once perceive a difference in their shapes; though he could not in the least say which was the cube, and which the sphere, he saw they were not of the same figure.

This result is the more important, in that it was this very boy who, as already indicated, had worked out a fully differentiated procedure of tactual inquiry and had also employed it with success.

A further example from HEYFELDER [22] has already been discussed (p. 66) in connection with tactual space.

VON HIPPEL'S little girl [23] was only four years old, but had shown

herself very skilful in the tactual trials, and was extremely quick in the uptake. The first visual object presented to her was a handkerchief, to which she responded with the word 'bright', with reference, of course, to the light-intensity, which she had already been able to ascertain even before the operation. A key, with which she had frequently played, was seen but not recognized. Other objects also (ring, hat, plate, glass) were only recognized by the aid of touch.

A week after the second operation (a *cataracta secundaria*), which resulted in good vision,

> I presented her with the cube and the sphere which she had so often had in her hands before, and asked her what they were. She could neither name them correctly, nor in any way describe their form aright; indeed, I remained very doubtful whether she had actually recognized them even as distinct from one another. I could reach no certain decision on this point, since on repeating the experiment several times on different days, and asking her whether the objects presented appeared the same to her, she sometimes said yes and sometimes no.

Now here there seems to be a misunderstanding of the question as to what this similarity of appearance is supposed to consist in (colour, for instance). We shall see, indeed, from numerous other examples, that recognition of the difference between two visual objects is normally the first act of identification in the perceptual process, and hence that, sensorily speaking, they already produce a perfectly normal visual impression.

DUFOUR'S case [26] is also very typical. At the outset, his twenty-year-old patient behaved in such a way that Dufour was convinced that his operation had been a failure; examination showed, however, that there was nothing wrong with the interior of the eye, and Dufour acknowledges 'that no anomaly of any kind was present'. On the second day of testing the patient was then shown a watch, and immediately gave its colour.

> 'Is it a round thing or a square one ?' – No answer. 'Do you know what a square is ?' – He positions his two hands so that they form a pair of surfaces which make contact almost at right angles along the radial edge. He thereby produces an angle, which is actually part of a cube. 'And a circle ?' – He again bends his hand round with the fingers pointing towards the wrist, and thereby produces an almost complete ring. After this fashion he therefore has some knowledge of circularity. In looking at the watch, at which his gaze is obviously directed, he remains absolutely incapable of saying whether it is round or cornered. However much I insist on an answer, none is forthcoming. I put the watch away again, without saying anything to him, and without letting him

feel it. On the following morning the same question; the same inability to answer. So I then let him feel the watch. No sooner has he taken it in his hand than he immediately says 'That's round, it's a watch.'

FIALLA writes, of his second case [28]:

> I showed her various objects, such as coins, a glass and a spoon, but she made no answer. A sort of stupid joy was reflected in her face. . . . I showed her my hand and asked her what it was; she looked long at it, without saying a word; I then took her own hand and held it before her eyes, whereupon she said with a deep sigh: 'That's my hand.' A blind person has no exact idea even of the shape of his own body; so that I first had to hold her own hand before her in order for her to recognize mine as a hand also. I then held up before her eyes a coin, a glass and a spoon, objects, in fact, which she knew by touch; she looked long at them without being able to recognize them; but as soon as I allowed her to touch these objects she immediately gave them their correct names.

In both cases there is no question of any lack of mental agility or situational perplexity; this, indeed, already emerges from the fact that what they do say is quite promptly and intelligibly uttered, while elsewhere they would sooner say nothing at all than something wrong. Dufour expressly draws attention to this point.

MAUTHNER [35] gives us a pertinent example as to the nature of tactual writing-processes:

> I now made her write some letters on the board. She did this, though without making use of her vision, but merely as the blind do, in that she followed with the chalk the movements whereby the index finger of the left hand was likewise tracing out the form of the letter on the board beforehand. When I then first made her turn away from the board and after a few minutes pointed to one or other of the letters, she could not read them, though they had been quite legibly written by herself and were also quite clearly seen.

This too, therefore, is a clear indication that the congenitally blind person, when he writes our alphabet, has neither the whole simultaneously spatial picture in mind, nor even a spatial grasp of the temporally successive sequence of movements of his hand as he writes, but carries out the writing-process as a dynamic interplay between muscular and motor sensations, which is largely given a rhythmical character. The individual letters are distinguished in his mind by the fact that the different individual motions are coupled together in varying sequences in order to produce the required total effect. Hence one cannot even describe the letters inscribed by the blind as 'successive wholes' (Krüger), for they are represented to his thought as letters in just

these very motor-sequences he has at his command, without becoming either simultaneous or successive figured wholes.

SCHNABEL observes, of his first case [33]:

> In the retinal image he recognized none of the objects which had previously been known to him by touch;

and of his second case [34]:

> The first visual tests were carried out sixty hours after the operation. In order to make sure whether the patient had really completely forgotten how things look, I slowly passed a number of objects before the child's eyes, without asking her any questions; first my hand, then a white cloth, a glass filled with water, a watch hanging on a chain and two large keys. The patient's face bore an expression of extreme surprise and joy, as with eyes fixed she followed the slowly moving objects. She insisted that she could see, but did not know what it was she saw, naming only the watch, whose two sides she described as yellow and white, and whose ticking she could hear. The visual tests undertaken on the following days had the same result. She did not even recognize the hand as such, but only its white colour and movement.

Here too, therefore, we have the same result, although the girl, having been sighted for the first five years of life, had no amblyopia or nystagmus, and to that extent presented the most favourable conditions that can possibly be found after a cataract operation.

Similarly favourable conditions were also present in FISCHER'S case [44], whose eight-year-old girl had still had some slight degree of vision until her sixth year, so that she too could fixate freely without nystagmus.

> Various things were now presented to her, which she must have known well from everyday life: an apple, a pear, plums, potatoes, an egg, bread, a knife, fork and spoon, a pencil, a box, a brush, a bottle, a watch, and her own doll. She knew none of these objects, but naturally she hardly needed to touch them with her fingertips in order, once guided by her tactual recollections, to know at once what they were. Spectacles from +9 to +16 D had no effect on recognition, nor did the child indicate whether she saw any better with them. A large grey cat was set before her; she followed the animal's movements attentively, but did not know what to make of the visual impression and remained quiet until, on touching it, she cried out happily 'The cat! The cat!'

It is very interesting to note the sequel to this experiment on the following day:

> The same kinds of fruit as yesterday were today put in her lap and similar specimens, carefully selected for size and colour, were shown her to see if she could pick the same objects out of her lap, and thereby,

> quite apart from the names of the objects, correlate her visual and tactual impressions. In vain! When shown the apple, she fetches out a plum, which is six times smaller, or even the pear (which is half the size of the apple). She does not recognize a single one of the things shown to her yesterday.

This experiment was thus carried out by getting her to pick out from her lap, without visual control, a seen fruit, in accordance with the visual impression of its size. For our purposes it would have been better if the test had been reversed, so that having touched a fruit blindly in her lap, she should then, from the tactual form and size, have picked it out from a number of similarly selected fruits lying before her; for she could not yet have been expected to estimate the size of fruit by eye. There would then have been yet a further process to be interpolated by the child, namely that of picturing the visual impression tactually, in her imagination, and only then of comparing this image with the tactual sizes and shapes experienced on searching in her lap. But even in the order adopted by Fischer it can be seen, to some extent, that touch does not convey a spatial impression of size; for if she had really had such impressions, then she would after all have been able, on feeling in her lap, to compare the tactual image and form with the visual impression which she did have before her throughout.

In summing up, Fischer repeats once more:

> In complete contrast (to vision in depth) there is the slow recognition of forms. It would naturally have been best, in testing the child, to begin with quite simple mathematical figures – triangles, squares and circles – and then to go on to the oft-discussed distinction between cube and sphere (Locke), cone and pyramid. But even the notions of triangle and square lay beyond the horizon of the child's understanding, and made it necessary to show her fruit, everyday objects and so forth. . . . She gradually learnt to know the other objects as well, but never recognizes those that have not been several times shown and named to her beforehand.

UHTHOFF I [45] devotes a very full report to the 'recognition of objects, persons and animals, etc.' His testing did not begin until after both eyes had become wholly free from irritation, after repeated attacks of this, and were carried on by regularly conducted series of observations over a period of three to four months. Unfortunately Uhthoff has not recorded this exhaustive material *in extenso*, even for the early days of testing, but has integrated all his observations into this one collective report. He opens by remarking:

> In the first place it may be stated that the patient recognizes no single

object by sight alone, with which he has not already become acquainted previously by touch, or some other sense, at the time of observation. He first had to collect his knowledge of any particular object by orientating himself about it, normally by touch, but at times by hearing, smell or taste, and comparing the impression thus obtained with that received by eye. Enquiries of this sort were conducted on a great variety of objects, animals, etc. (hat, knife, cloth, dish, fork, potato, match, matchbox, pin, egg, onion, chair, rabbit, dog, etc.).

Later, we are again told:

Even in the final period of observation, when the patient had already been using his sight for some months, it was constantly being brought home by further evidence that he could not recognize an object seen for the first time, even when it must otherwise have been known to him from the experience of his other senses.

This seven-year-old boy is a typical example of how little the congenitally blind trouble themselves, on their own account, about the forms of tactual objects, when not exhorted to do so by those around them. Uhthoff was actually compelled to spend three days in acquainting the boy with the tactual differences between round, square and triangular, though he does not seem to have undertaken these tactual exercises before the operation.

The boy appears initially to be devoid of all concepts relating to knowledge of the forms of objects, mathematical figures, etc. He cannot even tell by feeling whether a thing is round, square or triangular; here too it is primarily a deficiency in his mental upbringing. It need hardly be said that at first he can give no sort of account by sight as to what is round, square or triangular, what a sphere is, what a cube, etc. It took lengthy instruction to achieve this. After some three days' practice he is just about able to distinguish correctly by touch between a round object and a square one; after two more days, and having meanwhile had the opportunity of controlling his newly-won tactual knowledge of round and square by sight as well, he can also distinguish with fair certainty by sight alone between a round thing and a square one (e.g. a round china plate from a square white board).

But now here there is also another most important factor involved, and one that is very frequently referred to in our material, namely that the operated patient is initially incapable of simultaneously grasping the shape of a larger surface, and traverses the contours successively with his eyes instead, without being able at first to arrive at any total idea of the shape. We shall have to return to this point in more detail later on.

In Uhthoff's third case [56], Dr Axenfeld, who actually performed

the operation, had also taken a great deal of trouble with the patient beforehand and had instituted tests. But in this case too, though the boy was thus acquainted with tactual forms, in so far as a blind person can grasp forms of any kind, the early visual trials had a similar result:

> At the first test he showed no visual recognition of any of the objects presented though they were perfectly familiar to him by touch. He was shown a number of toys (ball, trumpet, etc.) which he had latterly played with while his eyes were bandaged, or when in the dark; but they were all completely unknown things to him.

And elsewhere it is said:

> But even during the later stages of inquiry it could be repeatedly demonstrated that he does not first recognize things by sight alone, even when they are quite well-known to him by touch.

In comparing the two cases (after a further follow-up study of the first), Uhthoff again remarks:

> Our second patient was at first completely unable to judge correctly of the form of seen objects by eye alone, though he is very well orientated tactually about round and square, for example, and shows himself much better instructed than our first case at the same juncture. When shown a coin against a dark background, our second case expressly describes it by eye as 'not round' to begin with, but corrects himself at once on touching the object, and very soon learns to name the simpler forms (round, square, etc.) correctly by sight as well.

Individual tests are unfortunately not recorded for this case either. But there can be no doubt of the correctness of the observations, in view of the large number of trials under similar circumstances.

A third case, operated on by Uhthoff five years later, is described by SEYDEL [58]:

> The exercises and tests were so arranged that the first objects to be placed in her line of sight were such as must have been precisely known to her by touch, such as a handkerchief, box, slipper, medicine-bottle, knife, fork, spoon, etc. It could be seen from her expression, and was also confirmed by herself on inquiry, that she had a visual impression of the objects in question; but she did not name a single one of them rightly with any assurance.

RAEHLMANN [46] did not start his tests until fourteen days after the final operation, so as to take full advantage of its effect from the outset; but so far as can be inferred from the choice of test-objects, he did not otherwise make any special preparations for these tests. This patient also began, on looking at the doctor's face, by declaring what he saw to be 'something white and dark'.

> The patient is shown a tin mug that he uses daily, about a yard away. He notices the presented object, but loses it as soon as it is moved out of the centre of his visual field (area of fixation) and into the periphery. Asked 'what object he sees', he replies 'A bright white thing.'

The object was again first recognized only by touch.

Not till the fifth day did Raehlmann go over to simpler objects:

> He is shown a sphere and a cube, both of the same coloured wood and of similar cross-section. On looking at them together he realizes that the two are distinct, but does not know which is round and which cornered.

FRANCKE'S case [50] is especially interesting, since it comes out particularly clearly here that even when the patient makes drawings he has no idea of the shape of what he is putting down on paper; that in fact he is reproducing with pencil on paper a succession of motor-impressions obtained on touching the object.

> During the first visual tests, on 28th December, the patient was shown a number of objects, scissors, a tumbler, a table-knife, an apple and a book, none of which he recognized. He did not even recognize the scissors, although he had drawn a pair of these before the operation.

The 'drawing' so produced by the twenty-six-year-old patient consisted quite crudely of a pair of scrawls of unequal length, unsymmetrically crossed and terminating at one end in loops for the fingers; it shows plainly that he had done nothing more than render on paper, by a purely dynamic act, two characteristically associated motor-sequences, taking care, however, that these motions conformed to the schema 'scissors' (crossing and two loops).

Thus in feeling the scissors and other objects he had obviously been able to take note, not of the form, but merely of the gross schemata of these objects, and had attended to the characteristic series of manual movements and the corresponding felt muscular sensations occasioned in traversing them. He could register these motor-sequences and also reproduce them with his arms or hands. Even though, for the sighted observer, something emerged which bore some resemblance to the required shape, in his own mind these drawing-motions did not relate to any clearly grasped 'tactual shape of the scissors', but consisted in the reproduction of a fixed schematic sequence of characteristic arm-movements, which he had obtained from the object known to him as 'scissors'.

It must also be remembered that this very patient had enjoyed the most favourable conditions prior to operation, since a certain awareness

of space in regard to both depth and shape was already fairly well developed in him. Thus even before the operation, for example, he could distinguish by sight between the longer and shorter sides of a piece of paper. It may well have been, however, that the patient himself had only discovered his powers of recognizing shape in the course of Francke's pre-operative visual tests; for otherwise he must already have had a few vague visual images, and would at least have been able to recognize the scissors thereby. In order to be certain about this it would, indeed, have been appropriate during the first visual tests to show him the same geometrical figures which he had been made to draw before the operation. For that he must actually have possessed at least a few quite vague visual images already can be seen from the fact that, after the operation, he was a great deal quicker than all the other cases in learning to use and develop his new sense on his own account. Thus on Francke's first showing him the geometrical figures at the third session, there was no longer any determining, at this stage, what ideas he had already had before the operation, and what he had by then abstracted, in the way of shape, from the objects presented during the initial trials:

> Having spent the first hours in merely making the patient acquainted with a number of objects, I began to investigate his recognition and understanding of geometric and solid figures. Here a notable difference became apparent, which was not, indeed, altogether surprising. For while the geometrical figures as such presented no sort of difficulty, it took repeated instruction with the solid bodies before he could distinguish them from the others. The ready recognition of simple figures with only one surface must naturally not be taken to suggest that they were immediately recognized correctly at first glance; the patient's amblyopia was much too extreme for that. But a circle and an oval were always correctly distinguished from a polygon, at least, whereas it already took longer and closer scrutiny, and even counting, with angular figures, to discriminate detail – more particularly, how many corners there were.

AHLSTRÖM [51], who likewise prepared his nine-year-old girl for her tests, and, as already noted, expressly states that in these tactual trials the quality of contact-impression and texture completely predominated over everything to do with shape, gives the following account of the first visual trial:

> . . .; but after a time this sensitivity to light disappeared, and she began to look around the room. The first things to attract her attention were her own hands; she looked at them very closely, moved them repeatedly to and fro, bent and stretched the fingers, and seemed greatly astonished

> at the sight. She was shown some objects, which she had readily perceived before by feeling, such as a knife, feather, glass, book, etc., as already mentioned above; but now that she was required to bring sight into play, she could not recognize them; she said she could see the objects clearly, but as to which was which she seemed to have not the slightest idea. . . .
>
> Geometrical figures, such as squares and round discs of paper, she soon learnt to distinguish and name correctly.

The case jointly treated by MOREAU and LEPRINCE is extremely notable, in that an experiment was post-operatively tried on the boy which he had often made himself, before the operation, albeit for a different purpose: he had been in the habit of waving his hand to and fro before his eyes and took pleasure in the changes from light to dark, but had sought in vain while doing so to learn anything about the shape of his hand, of which he had obviously been unable to obtain an idea by feeling, as became apparent in the first visual tests. Moreau now arranged to light up his own hand, by itself, in a dark room, so as to make it easier for the boy to concentrate his attention on this one object alone, and then waved it to and fro before his patient's eyes. The result was negative, since it produced on him the same effect of an alternation from light to dark. He paid no attention at all to the shape, nor did he follow it by eye, but took purely sensuous note of the change in the amount of light presented to his eyes as they stared constantly in one direction. Only when prompted by questioning did he make an attempt to identify, and then produced exactly the same data as before the operation, namely purely qualitative material. Leprince writes:

> On the following days the tests were devoted to presenting familiar objects, knives, forks, spoons, etc. Our numerous questions invariably yielded the same result: 'I don't know,' followed immediately by a further answer: 'That's shiny.'

Later we read:

> The test with cube and sphere, already referred to by Diderot in 1749, was also administered by Dr Moreau, and by eye alone the boy was incapable of recognizing the forms in question.

These passages may suffice. They show at least, that the inability of the newly sighted to recognize shape in visual objects cannot be simply accounted for by attributing it wholly to hazy, amblyopic vision. In the cases referred to, these particular factors hardly entered at all, since the visual weakness largely cleared up in the course of the tests, and in some cases, indeed, acuity of vision had already been corrected by

spectacles. Yet these patients show by their whole attitude even to direct questions about shape that everything specifically concerned with this is, as it were, foreign to their thought; that the notions of shape they thought they possessed while blind had basically nothing whatever to do with it, being really a schematic, prefabricated, constructed affair, which the congenitally blind have created, not so much on their own initiative, but so as to accommodate their modes of thought and expression as fully as possible to those of the sighted. In order now, in pursuit of this aim, to fill out in their minds the spatial, which they do not understand, with some sort of content that they *can* grasp, they are obliged to create these schemata, in which the spatial is transformed into the temporal. But the first post-operative visual tests make it evident throughout that in their own minds these schemata are in no sense combined with anything genuinely spatial. WARDROP'S forty-six-year-old lady gives quite unmistakable expression to the sense of disillusion that results:

> On the sixth day, she told us that she saw better than she had done on any preceding day; 'but I cannot tell what I do see. I am quite stupid.' She seemed indeed bewildered from not being able to combine the knowledge acquired by the senses of touch and sight, and felt disappointed in not having the power of distinguishing at once by her eye, objects which she could so readily distinguish from one another by feeling them.

2. Influence of Non-Visual Impressions

Before entering further on the process of development by which visual perception of shape is formed, we must first take account of that group of cases in which the visual shape appears to be recognized 'correctly' at once, or is at least properly named in each instance. We shall have to determine how this seemingly purely visual judgement is arrived at, and will see that it is invariably a matter of inferences derived either from *knowledge of the situation*, or from a *participation of other senses* not observed by the doctor, and in each case, therefore, from pure intellectual induction. (A proportion of these cases have already been briefly referred to in connection with tactual space, where they were drawn upon to illustrate the working of the schema.)

In HOME I [13], for example, the position is perfectly plain. Here both factors were at work, on the one hand the special situation of the operation as such, and in addition the aid of hearing, in so far as the patient was frequently questioned by Home in the course of the

operation, so that he not only knew, but also actually felt that the surgeon was operating on his eye and talking to him, and must therefore be standing as it were face to face 'in front of' him. This knowledge of the situation was manifestly bound to supply him with the appropriate answer. Thus when we are told that, immediately the operation was over,

> On my asking him what he had seen, he said, 'Your head, which seemed to touch my eye', but he could not tell its shape,

the first part of his answer is simply drawn from his knowledge of the situation; and on the question of shape he then had sufficient time in bed to think about it, and the opportunity to feel out the shape of his own head. Two days later, therefore, when the same situation was repeated and Home was examining his eye, he was already prepared for it:

> He said he could see several gentlemen round him, but could not describe their figure. My face, while I was looking at his eye, he said was round and red.

Here too, the first part of the answer results from his having already established that gentlemen were present at the examination, and knowing approximately 'where' they must have been standing; and the second part, apparently given spontaneously, is due to reflection, in the interim, on the question put by Home on the first day. Thus in order to make this remark there was no need for him to have already acquired the visual conceptions of 'man' or 'round' (though his degree of pre-operative vision did not make it impossible for him to have done so).

Similar features are present in HOME II [14]. Here, after an initial trial with cards, all of which the boy described as round, it is reported, two hours after the operation:

> Upon being shown a square, and asked if he could find any corners to it, the boy was very desirous of touching it. This being refused, he examined it for some time, and said at last that he had found a corner, and then readily counted the four corners of the square; and afterward, when a triangle was shown him, he counted the corners in the same way; but in doing so his eye went along the edge from corner to corner, naming them as he went along.

In this instance, therefore, the wording of the question puts him on the right track; the task of 'finding corners' is quite explicitly given to him; and in solving the problem he is naturally able to draw on all that he already knows from touch about the peculiarity of corners, more

especially the sudden change of direction, or rather the sudden falling away when traversing an edge, which he now experiences when scanning by eye, just as he has done when touching with the finger.

This latter account is also important for its evidence of a successive traversing of contours by the wandering eye; for here too it is manifest that the figure presented in this primitive mode of vision has no effect at all in producing an immediate overall impression, though in view of its small size in relation to the patient's field of vision, it is certainly present all at once there. The evidence shows, rather, that the newly sighted patient is wholly preoccupied in grasping the squareness of the figure, that he first has to work out the shape apperceptively, as it were, on his own account.

The correct replies given in the cases of WARE [11], RAEHLMANN I [46] and WARDROP I [15] (*cf.* p. 33 f.) are due solely to knowledge of the previously acquired tactual schema of the space in question.

DUFOUR [26] is much astonished when his patient is able, on the fifth day of testing, to recognize a pocket-knife 'after slight hesitation' as a 'knife'. But subsequent questioning elicits a sufficient explanation:

> At table on the previous day he had learnt without my knowing how to distinguish the appearance of a knife, fork and spoon.

What is striking here is that in this affectively conditioned activity of eating, this single though long-sustained contemplation of the cutlery should operate so lastingly as to enable the youth to recognize the pocket-knife, which looks quite different, on the following day. Here too, Dufour himself provides the relevant clue:

> M. had apparently inferred the nature of the new object thanks to the most striking common feature, the presence of a glistening blade.

What is involved here, therefore, is not an abstraction of any kind of the essential features of a knife, but merely the qualitatively similar impression of something glistening, which assisted his memory. He had retained, not the shape, but the material object word attaching to this qualitative impression. Soon afterwards, however, the situation was already quite different, as we shall see in due course (*cf.* below, p. 183).

It might also occur to one to cite the following passage from GAYET [40] to show that it is none the less possible to achieve an immediate grasp of the significance of a visual impression experienced for the first time, e.g. by way of a fear-reaction:

> The first thing I showed her was a candle-flame, which she certainly claimed to recognize, though it inspired her with considerable fear.

> This was quite understandable, since up to now 'fire', as she called it, had appeared to her inseparably bound up with the harm it can do, and because she had only been acquainted with it till now through tactual sensation, without having any notion of distance.

An exact report of the situation would have been pertinent here, for the above wording does not exclude the possibility of the words 'flame' or 'light' having been mentioned beforehand. In view of the apathy otherwise displayed by this sixteen-year-old girl, we cannot assume her fright to have been due solely to seeing the candle-flame (despite the dazzling that was doubtless occasioned thereby); it may have been due, rather, to being asked, 'Do you see the candle-flame?', so that the word 'flame' could have suddenly evoked the whole schema 'fire', and so aroused alarm at what she saw. A certain degree of bedazzlement may naturally have contributed to this, by awakening in her the idea of close proximity, and hence of immediate danger. It is the accompanying anxiety which marks out this particular impression so distinctly that the sight of flame always produces the same effect on her; in contrast to all other visual data, in which she takes so little interest as to create an impression of passive resistance.

One might have doubts about the case of DOR [41], who remarks, without further explanation:

> On removing her bandage on 5th November (one day after operation), I held out two fingers to her, which she took for two little white sticks; I let her touch them, whereupon she immediately recognizes them as fingers. On the 6th she recognizes a hand and five fingers, without the aid of touch; I show her a half-opened knife: this is a white stick and a grey one; their size and colour are reported from some distance away. A key is a ring, a straight rod and a square at the other end; but this time touch is still required for recognition of the object.

But here too, it seems, the answer to the riddle lies close at hand; Dor gives the following account of her pre-operative powers of vision:

> The pupil is completely obstructed, but the patient has good sensitivity to light and good projection. She sees the shadow when an object passes between the light and her eye, and can also distinguish very vivid colours, as when a large coloured object is lit up by the sun; she even counts the tree-trunks along a promenade by the shadows, but sees nothing of the shape of things.

Since she was also a professional organist, it is at least possible that the black keys on the brightly lit manual had been recognized by eye as 'sticks', or that she had already acquired an admittedly vague visual image, especially from coloured shadows, of the more elementary visual

forms; unless we are to assume that, prior to the first, or between the first and second day of testing, the young lady had made her own preliminary experiments, which were responsible for her success.

DUNAN [42] writes:

> After looking at it (a paper disc) she immediately told me 'It is white; it is round.' I ask her in what direction it lies, and she reaches out a hand to grasp it. I offer her two rectangles of different sizes, cut from the same paper, and ask her which of them is the larger. She tells me without hesitation.

But Dunan did not undertake this first experiment until ten days after the operation (not having heard of the case at all until then), and throughout the whole of the intervening period this thirteen-year-old girl had had virtually no supervision. He subsequently tries to show by all sorts of logical deductions that this state of affairs exactly corresponded to that prevailing on the very day of the operation; though he has admitted at the outset:

> From the psychological point of view, the only thing to be regretted is that Dr Trousseau, after so skilfully performing his duties as a surgeon in restoring her sight, did not take equal trouble from the beginning in studying the nature of her vision. So far as M. Daguillon (the assistant surgeon) is concerned, he certainly put questions to her, some of which are of genuine interest; but he did so without any special regard to the theory of external perception, and more from the clinician's point of view than that of the psychologist.

Now since these questions, and the answers given to them, have not been recorded, they would have been better dispensed with altogether; for such questions must naturally have given the girl some help in teaching herself to see. We are told nothing about them, save only that at one point it is said:

> A few moments after removing her bandage for the first time, M. Daguillon (the assistant) had shown her his hand. The child was naturally unable to recognize it; she told him that she saw 'something bright and then holes.'

This already answers more closely to the true state of affairs: here she is simply reporting the purely qualitative datum actually presented, namely something bright, standing out sharply against the dark background. Thus she obviously did not grasp the strongly differentiated shape of the hand. Of particular note here, however, is that even at this first trial she takes in the bright and curiously structured surface of the hand as a unity along with the 'holes' between the outspread fingers,

and conceives of these holes as in some sense a background to this bright and differentiated surface. That represents a notable contribution to the problem of figure and ground. It may further be noted at this point that she also shows thereby how broad differences of depth are given to her mind, even in monocular vision.

When, on the other hand, a case like RAEHLMANN II [47] 'describes a sphere held before her as a large yellow turnip' and immediately distinguishes correctly between a round disc and a sphere, a cube and a square, the operative factor here is

> that the patient is in full possession of spatial ideas; [because] even before the operation, with her limited powers of vision, she has learnt so much about the space accessible to her touch.

It is for this reason, indeed, that we have reckoned this case among the six who already possessed a visual awareness of space prior to operation.

GRAFÉ [49] did not in fact begin testing his fifteen-year-old boy until some two months after the operation, but like Dunan he also tries to reconstruct from these tests the situation immediately after operation, and to prove it to have been the same. In so doing he relies on the statements of the patient himself. The matter of the rosary (*cf.* p. 96) was cleared up by the boy himself; he recognized it by ear. Grafé gives another example of apparently immediate recognition of visual objects at first sight, assisted by tactual imagery, and says of it:

> When the bandage was first removed from his right eye, the surgeon took the opportunity and made some provisional tests, as a preliminary to those which were to give final confirmation, a month later, of the degree of vision that he had restored to the patient. He showed the latter his hand, his fingers and various objects of simple form; the lad saw them and was able to distinguish them, counting, for example, the fingers held out to him, noticing a bright patch (a ring) on one of them, and, what was still more astonishing, actually recognizing some of these objects. [There follows the tale of the rosary] . . . The boy told me he had recognized the fingers displayed to him. I expressed my astonishment at this 're-recognition', and repeated the question put concerning the rosary. He answered without hesitation: he had known what fingers were, having, indeed, been regularly able to feel and count his own fingers. 'But,' said I, 'was it not the first time that you had perceived fingers in visible form? What reason had you for giving this visible form the meaning you ascribed to it?' He fell silent, which often happened when I pressed him too hard; though I have good reasons for not regarding this as a sign that he had caught himself telling a lie. Before looking at the doctor's hand he may perhaps have examined his

> own hands, felt them over and moved them around, in such a way as to have set up an association, in regard to this object, between the data of touch and sight.

Grafé now produces a third example:

> The boy insisted that the crucifix hanging in front of him, some three or four yards from his bed, had straightway appeared to him in its characteristic shape; so, too, with a small magnifying-glass, which happened to be lying on his bed, and which he noticed at once in spite of its small size (doubtless owing to the reflections from it): he was positive that he had recognized the roundness of this glass, even before picking it up. When the sister showed him a pair of scissors, he could at once tell the blades from the handles.

Grafé himself conjectures that the boy must have seen more, before his operation, than was generally supposed, or than the patient himself admitted.

> I questioned him on this, and cross-examined him in great detail; his admissions on the point were limited to the fact that he saw 'something' when holding an object close to his eye and rather to one side. 'I see daylight well enough,' he said, 'and in the evening I can often distinguish objects as well.'

In attempting, on the strength of this assertion, to get a more exact assessment of his visual powers, it emerged that with a stick in his hand the boy was able 'without much tapping around' to point out the corner of a piece of furniture that stood within his reach. After administration of atropine the effect was enhanced, so that the boy himself

> was very pleased that something had been done to his eye which enabled him to see more clearly. At the edge of the cataract [the doctor could] see the back of the eye, the red colour of the retina and a number of vesicles.

In both eyes the lens-capsules were also reduced in size. Thus his seeing of 'something' might have been quite considerable. But since, on the other hand, his nystagmus was very persistent, his powers of vision certainly cannot have been great enough to allow him the habitual use of them. In view of this nystagmus, however, all the above particulars also appear somewhat doubtful, and the more so since Dr Bribosia (the surgeon) himself remarks at another point that the boy could only see properly a month after the operation, when he was fitted with convex spectacles. It may therefore be assumed that the boy's statements were at any rate greatly influenced by his knowledge of the situation, or that, as in the identification of the rosary, he had been unconsciously assisted

by other sense-impressions which the doctor had seemingly failed to notice. For how could he have recognized such a thing as a magnifying-glass at first sight, when he could not even have known it by tactual experience? We may certainly take it, rather, that the process of recognition had already begun at an earlier stage. In all probability the visual impressions, both of the crucifix and the magnifying-glass, which he correctly interpreted at once, were not his first impressions of these objects; on the contrary, he had previously orientated himself tactually in his sickroom during his hours of solitude, and had thereby learnt: at the foot of your bed there is a crucifix hanging on the wall; and in searching about while his dressings were being changed he will have found that the doctor had left a magnifying-glass on his bedspread, which had just been used for looking into his eye. So he says to himself: if you now look 'straight ahead' (i.e. with the head in normal position) you will find on the bedspread a magnifying-glass (which he was already curious to look at), and on the wall a crucifix. Prepared in this fashion, by possession of a tactual schema (both of the structure of the objects and their position in the room), it is not so very surprising then that the crucifix and the shape of the magnifying-glass should be at once forthcoming in accordance with this tactual schema, and to that extent recognized. This interpretation may seem to smell of the lamp, but it is founded on the facts of the situation and the rest of the boy's behaviour.

The recognition and counting of the fingers is also intelligible in the circumstances, for the patient will certainly have felt the hands of the surgeon sitting at his bedside and slowly unwinding his bandage; hence it is quite probable that at the end of this operation he saw them still at work, knowing that they were the very hands that had just removed his dressing. But this knowledge at once gives him all he knows of hands, namely, that they consist of a palm and five fingers. When, therefore, he now has the same hand displayed to him, he is able, with all he knows about this visual object, to grasp at once its characteristic five-fold shape, and knows what he has to count when fewer than the full number of fingers are then presented for enumeration. As the case stands, it is not even necessary that he should meanwhile have had surreptitious opportunities for studying his own hand (though he may well have done so, since it took half an hour to change his dressings).

The crucifix and magnifying-glass having once provided him with the contrast in visual form between round and straight, it was also possible for him to distinguish, in a pair of scissors, between the straight crossed blades and the looped handles, to determine their form, and,

by virtue of their coincidence with the tactual schema, to recognize the total visual object as a pair of scissors. It may also be supposed that he did not reach this conclusion entirely on his own, but was directed to points of detail by the sister's questions, and thus to some extent guided in his thought.

Since Grafé expressly credits his patient with 'a very alert intelligence', he is quite right to feel some scruples about erecting all-too-sweeping conclusions on such merely verbal evidence.

> Our patient claims never to have mixed up the plane figures, such as a circle and a triangle or 'half-square' (as he called it); but it is true nonetheless, that as soon as he could devote himself to these comparisons it was seen how all objects that he looked at attentively were taken into his hands, manipulated and turned on every side. If, therefore, he was able, on a single visual appraisal, to recognize a cross, a rosary or a pair of scissors, is it really quite certain that he was not basing his conclusions on some sort of analogy between these visual presentations and other visual phenomena which he had already associated with tactual sensations? To be sure, in all these cases, it took him no time at all to formulate his judgement; for the objects of which we have spoken were given to him, as it were, immediately on his recovery.

This also leads us to conclude that, as already described, the boy had approached the visual objects in question with preconceived knowledge of them; and hence that it was not a matter of purely visual processes of recognition, based on a tactually acquired notion of shape.

FRANCKE [50]

> notices at the third trial that a variety of new objects are either quite correctly identified, or at least recognized in essentials according to their shape. Thus an unfolded handkerchief, a hat, a cap, and a purse were recognized as such; on looking at a clothes-brush the patient says: 'It seems to be a brush', without being able to specify its nature more exactly; and he takes a cup for a pot. Although, in identifying the handkerchief, hat, etc., he continues to express himself with caution, whereas he names the objects known to him from previous sessions with fair assurance, it is nonetheless notable that individual objects are recognized by sight alone. I need hardly repeat that there could have been no instruction from other patients.

Here, at all events, the case is altered, in that this young man of twenty-six had already made the maximum use of his residual vision prior to the operation, and had also entered with great ardour into the post-operative tests, in the hope of being able thereby to speed up his acquisition of visual imagery and to abstract the main principles of form. Thus he knows how to utilize this stock of visual ideas in order to

describe the shape of seen images that are new to him. So when such a visual description happened to coincide with a previously acquired tactual schema, he therefore had a footing on which he could venture a judgement. Francke himself, at all events, believes him perfectly capable of such feats of intelligence.

But in this case also, we must proceed with great care. For if, on discharge, the patient was still so highly amblyopic 'that with a correction of +10 D to each eye he could only count fingers at minimal distance', while his nystagmus persisted virtually unaltered, we cannot discount the suspicion that here too other sense-impressions were surreptitiously contributing to what was supposed to be purely visual recognition. For it is curious that the objects he recognized (unfolded handkerchief, hat, cap and purse) were all things which have an effect, at such close quarters, on the olfactory receptors. How easy it is for the judgement to be affected by such contributory impressions, we shall discover from further examples at a later stage.

SEYDEL [58], for example, follows up this suspicion and finds it confirmed:

> She used every impression from her other senses with much greater readiness and promptitude than her visual impressions, and it was an easy experiment to mislead her by making some sort of noise in the background. Thus if a large bottle was set before her, and money jingled nearby, she had no hesitation in deciding on 'money'.

Particular importance attaches to LATTA'S case [60], where on first sight of geometrical solids (ball and brick) the patient recognized their form without having touched them or had any other sort of assistance; and this by an imagined feeling over of the visually presented shape.

We have already reviewed this case at length in dealing with the space of touch (*cf.* pp. 58 f., 72 f.), because we wished to draw conclusions from his behaviour as to the nature of the tactual given. What chiefly matters in the present connection is that the man succeeded in following by eye the contours of the shapes presented, while at the same time feeling them over in imagination; and was able in this fashion to establish that the tactual and visual sequences were identical.

It would therefore be the sole instance appearing to point to a relation between tactual and visual shape. But even this one case in fact goes no way towards proving any such thing; anything, that is, that would allow one to maintain that the patient had acquired a pre-operative conception of tactual shape, by tactual methods, which then served him as a clue, after the operation, in the recognition of visual shape. For in point

of fact he reversed the process: he did not 'recognize' the visual shape from the tactual one, but on the contrary transformed the visual shape accessible by eye into a sort of tactual raw material to be worked over in temporal succession, and only discovered the recognition-features of this shape by imaginary touching. In other words, he ascertained that this visual image ought to feel 'like this', and that 'that' must be a corner; its establishment as a 'corner' conveyed to him the *information* 'cornered', but not, as it were, a corresponding tactual shape. He thus performed in imagination what the other patients actually do by hand, when they take hold of the visual object and thereby seek to relate the two impressions together. As we shall see later, Latta's patient was the only one to carry out this operation so clearly at very first sight; but the other cases do likewise at a later stage of their learning to see.

From what has been said it emerges, therefore, that a definitely structured conception of shape is not a primary factor in the vision of our patients; and that a lasting conception of visual shape cannot in any case be associated with an object (cube or sphere) known by touch.

II

FURTHER DEVELOPMENT IN THE USE OF SIGHT

The foregoing conclusion shows that the definitely structured shape of visual objects is something entirely new to the patient, for which touch has provided him with no spatial relations, apart from the schema. Hence the perception of a visually given shape represents an absolutely new achievement on the part of a person who has just obtained his sight. In order now to bring out this fact in more detail, and thereby also to show that our reservations concerning the second group of cases are justified, we shall attempt, as briefly as possible, to demonstrate positively how the ideas of shape gradually develop in the course of learning to see, and what stages of development are normally traversed by the patient in doing so.

Here too, the abundance of material is a great advantage, since the individual authors were only rarely able to observe every single phase of the learning-process and work it out exactly; this for the simple reason that the doctor cannot be constantly attending to only one patient. FIALLA [28] quite rightly says:

> It would be interesting to observe the cultivation of sight among these young people at close quarters; but for this purpose one would have to be constantly in their company, for every moment is instructive; they are touching all the time, continually seeking to assure themselves that they have awoken and can see, and ceaselessly attempting to store their memories with the external impressions impinging on the retina.

MOREAU for that reason had the sister-in-charge with a notebook in continual attendance on the one patient alone.

But when we supplement the features special to any one case with those from others, there is so much evidence available for every phase of the learning-process, that a unified picture can be obtained. The description of the purely qualitative features of the first visual impressions is bound, however, to fall somewhat short in this respect, precisely

because the tests of this were subject to special disturbances, making it difficult to describe them.

1. Pure Sensation

On opening the eyes in first attempting to see, there occurs the initial *stage of purely visual sensation*, though this can be clearly demonstrated only in a few cases. It might occur to one to call upon the cases of the first group (p. 107) for this purpose; this, however, would be feasible only if one were also prepared to include the inability to understand the first visual impressions under the heading of sensation; and for that there is no justification, save only in cases like MOREAU'S, where we are dealing with an apprehensive, frightened and nervous child, in whom the visual experience is still something purely inactive. For although the other cases may also have been no less completely helpless at first when confronted with visual images, so that we cannot yet speak of perception, they had nevertheless been prepared and directed to their task beforehand, by the doctor or psychological observer. They had taken on the task, and on encountering these first visual images their minds were at work. They could not, indeed, understand what was visually presented to them, but were making the effort, and were to that extent already perceptually active. This is still more evident with the patients of the second group (p. 117) because in their case these efforts had already led indirectly to a certain degree of success. When CHESELDEN [5] writes, for example:

> He knew not the shape of anything nor any one thing from another, however different in shape or magnitude.

this state of affairs no longer relates to the concept of sensation alone, because even at this stage the patient is deliberately concentrating wholly on recognition, though he has not yet met with success.

By contrast, the state of sensation is very well typified in the following passage from GRAFÉ [49]:

> To begin with, the newly-operated patients do not localize their visual impressions; they do not relate them to any point, either to the eye or to any surface, even a spherical one; they see colours much as we smell an odour of peat or varnish, which enfolds and intrudes upon us, but without occupying any specific form of extension in a more exactly definable way.

In this initial stage of pure sensation, vision is confined to the purely physiological process of the reception and conveyance of stimuli to the

visual centres. For the individual, it remains a quite passive influx of visual impressions, which do nothing, as yet, to induce him to emerge from his passive state and to try, for his own part, to take up some sort of mental attitude towards the chaos of colours presented to him.

Such a vacuous functioning of the physiological mechanism is something which it is hardly ever given to the normally sighted adult to experience. One might perhaps instance the situation in which we have found ourselves on noticing that, lost in thought, we have reached the end of a road without having any recollection of even the smallest detail of the route. The concept of sensation would apply to such a situation to this extent, that here too the mental element is virtually absent, although the sensorily presented visual impressions have impelled us to motor reactions throughout the journey; but these reactions are by nature better referred to as reflex actions, in which a great many repetitions of the same motor reactions have led to the disappearance of any conscious process of perception. Among our patients, the state of sensation is most clearly evidenced in the American GETAZ case [65]:

> Then the girl went through the experience that we all go through and forget, the moment we are born. She saw, but it did not mean anything but a lot of different kinds of brightness. She wasn't even positive that these strange new sensations were coming through her eyes until she proved it by closing the lids and finding that this stopped the sensations. . . .
>
> Back of her hand was a background of various kinds of bright blurs which she assumed were different colors. But there was no shape to anything or distance.

In this case also, the state of sensation was very soon displaced by a contemplative attitude towards the visual images so presented.

FRANZ [17] provides another example:

> On opening the eye for the first time on the third day after the operation, I asked the patient what he could see; he answered that he saw an extensive field of light, in which everything appeared dull, confused, and in motion. He could not distinguish objects. The pain produced by the light forced him to close the eye immediately.

In this case the patient is only given his task on opening his eyes, and owing to the painful glare he never even gets to the point of actually undertaking it. His visual experience is subsequently described from memory only. As the eighteen-year-old son of a doctor, the account given of this experience may well derive from himself, and the more so since he describes a condition which Franz was only later able to confirm, namely that he was confronted with non-visual appearances in the

shape of floating spheres, which passed off some days later. Even four days afterwards, owing to the short time he could keep his eyes open, he had not yet emerged from the state of pure sensation:

> When he directed his eye steadily toward an object, the visual impression produced by the object was painful and very imperfect, because the eye, on account of its intolerance of light, could not be kept open long enough for the formation of the idea as derived from visual sensation.

The vision of such a patient can remain for a long time at the purely sensory stage, if for any reason the new visual impressions are burdensome to him. For the newly sighted person, the desired transference to the visual sphere is naturally associated with all sorts of difficulties, which may reside, for example, in the fact that the whole motor apparatus of the eye does not respond to his will; hence his visual impressions are so fleeting and unstable that he cannot understand the instructions and questions put to him, or at least cannot relate them to the impressions received. Since, moreover, he can find no means of access to the novel impressions even in his previous methods of orientation, he is apt to fall from the outset into a state of despondency, if not of actual resistance to the practice of his vision. This impression emerges, for instance, in the following passage from SCHNABEL [33]:

> Failing the use of repeated entreaties, persuasions and threats to draw the boy's attention to the objects presented, he was quite indifferent to them and made not the smallest effort to look at his limbs, his clothes, his eating utensils or anything else in his environment. If I covered up the operated eye and kept quite still in the room, he never stopped calling for me, but did not attempt to remove the patch from his eye and look for me. Fourteen days after the operation, when all trace of inflammatory irritation had long since disappeared from the second eye, and I had already established by repeated ophthalmoscopic examination that the media were perfectly clear and the back of the eye quite normal, I took the boy to the window while the Corpus Christi procession was passing along the street below. He went into ecstasies on hearing the music, announced correctly every time when the cortège stopped and when it got moving again, remarked that the people below were praying, but made no attempt to see anything of the colourful scene. I held the child so that images of the passers-by were certain to have met his eye, but could not induce him to engage in visual perception. When he gave me correct answers during the tests, and I praised him, he was very pleased at this; but seeing gave him no pleasure, nor did it awaken the slightest interest or curiosity in him.

One might well gain the impression here that in this case the visual

centres were not receiving the incoming stimuli in the shape of a conscious image at all, or that owing to atrophy of the optic nerves there was simply nothing reaching them. That would have been an error, however, for the condition was really one of pure sensation, and the failure to extend it by perceptual activity was due solely to lack of interest on the part of the patient; as is shown by the fact that, after an operation on the second eye, the boy was eventually coerced, under intensive pressure, into an adequate use of his sight, Once it had proved possible to awaken his interest in colours, whose recognition was least open to disturbance by nystagmus, the boy himself began to cooperate in the speedier development of his vision, and thus the spell was broken.

GAYET [40] was unable to break down resistance to the efforts required in learning to see; and this although colours also had some effect here.

> The first time I took her into the lecture-room of the clinic, which looks out over the Rhône and commands an extensive view of the quays and houses on the other side, I noted some signs of surprise; but nothing came of it, and although she was repeatedly exhorted to look in front of her, I could form not the least picture of the impression she had received, and when I tried to get her to talk she immediately began repeating my own words parrot-wise. From this day forth there began an educational process which was extremely wearisome to her, and which I alone could conduct, for some time, since I alone had sufficient influence over her to subdue her tantrums and her tears.

In this case too, ophthalmoscopic examination showed that 'objectively speaking, the visual apparatus was restored and whole', and observation also showed 'that she often evinced unmistakable signs of seeing' – in other words, that her visual impressions were not always purely sensory in character.

In MARC-MONNIER'S case [38], there was equally little success in overcoming the reluctance in learning to see. Here again, vision remained, with few exceptions, at the level of sensation.

> When Roger found himself confronted for the first time with a landscape, he saw nothing but a confusion of forms and colours.

He only made use of what he had already employed before operation, namely his acquaintance with colours. For M-M. goes on:

> He then said, very slowly: 'I see something blue', which was the river; 'and something else green', which were the woods; 'and something else blue', which was the sky. But since he could not touch any of them, he took no interest in them at all.

Elsewhere it is said:

> He does not know what he is seeing, and everything that vision tells us concerning lines, contours, proportions, distances and motions is unknown to him.
>
> All his ideas were furnished by touch and hearing; those excited by eye arrived too late; he took no interest at all in acquiring new knowledge; he continued to behave like a blind man.
>
> My own opinion is, that he never saw anything but a confusion, and that this was his own fault; that is why your world, as it appears to you, was and remained strange to him. All the images which delight your painter's eye flitted through his mind as a jumble of impressions, without his attention being drawn to them.

In this case also, there is incontrovertible evidence that this persistence of the sensory state, in which he merely endured visual impressions, as it were, as a condition that was unfortunately inescapable, was actually based on unwillingness only, and not on incapacity. For as soon as he became emotionally engaged in the visual process, his attitude to these impressions was in no way different from that of other patients. Thus his blind sweetheart, later his wife, made the following experiment with him, and thereby sought to impel him to learn to see:

> One day, during the vine-harvest, she picked a bunch of grapes and showed it to her lover from a distance. 'What is that?' she asked him; 'It is dark, blue and shiny' (i.e. purely qualitative features). 'Anything else?' – 'It isn't smooth, it has bumps and hollows.' 'Can one eat it?' – 'I don't know.' – 'Then take it and try.' As soon as he touched the bunch, he cried: 'But they're grapes!'

Even his reason for being so unwilling to use his sight was a purely emotional one: he wanted to stay blind, because otherwise he would have had to leave the blind institute and thereby be separated from his sweetheart. On this separation being effected for some time, against his will, so that he was only allowed to see the girl under supervision for an hour a day, he finally said to her:

> No, really, I can't stand it any more; I want to be sent back to the asylum again. If things aren't altered, I'll tear my eyes out.

There are numerous other cases of this sort, in which the state of sensation persists for a long time, because the patients in question cannot be got to use their new powers of sight, although it is established that they actually can see. They enjoy the brightness and seek it out; they are sensorily aware of all visual images, but will not bestir themselves to furnish these impressions with meaning. They experience

visual impressions, brightness and colours as something purely circumstantial, as a sort of medium, in which they move like a swimmer in water. Having made no effort to acquire these strange impressions, and being sufficiently conversant with the external world without them, they are likewise indifferent to such novelties. One often has the impression, in fact, that the reason for this passivity is either complete stupidity, or else that of the blind man from Paris. For in his *L'aveugle qui refuse de voir*, Paris 1771 – communicated by Hedwig Schmidt (*Klinische Monatsblätter für Augenheilkunde*, vol. 76, 1926) – Cerfvol tells of a blind man who gave the following excuse for refusing to undergo the operation:

> Everyone who has strength must work. But apart from the difficulty of having to start learning again at my age, and the formalities involved in obtaining the right to practise my calling, would I then be sufficiently well paid? I assure you that I am happier as I am: no responsibility, no blame. I defer to nobody, have no need of anyone as patron of my work. People simply press money into my hand, without waiting for me to stammer my gratitude. In giving me sight, you are delivering me over to the burdens that you bear; my blindness is my fortune.

A similar example of refusal to make use of vision, due to lack of nterest or complete stupidity, is furnished, for example, by VURPAS-EGGLI [52] in the case of two boys of between four-and-a-half and five, who were both somewhat neglected, mentally and physically. When their eyes were unbandaged for the first time, nothing could be got out of them.

> So of necessity we could do no more than confine ourselves to observing how they reacted to the light. To our great astonishment, there was no psychological reaction whatsoever. Our patients continued to behave exactly as they had done in the past. And this was the plainest fact, the most obvious finding, of all that we encountered during the entire course of our inquiries, namely that there was no change of any kind in their whole bearing and demeanour. The same posture was maintained, the same heedless movements, the same method of orientation in regard to surrounding objects.

Eight days later it was still the same:

> We were struck by the fact that his behaviour had still not altered in any way, though it was now eight days since the restoration of his sight; the same habits were preserved, exactly as before.

That the boy could in fact see, is shown by the following experiment:

> The child can see, but will not make use of his sight. Only when pressed can he with difficulty be brought to look at objects in his neigh-

bourhood; but more than a foot away it is impossible to bestir him to the necessary effort. At a second trial we prevented him from using his hands and thereby actually got him to perceive a cake lying at hand in front of him, which he could have seen under these conditions with perfect adequacy.

BEER [10] relates of a twenty-one-year-old girl:

Even before the operation she was dull and quite literally spiritless, as I have never yet seen such a patient before. Whenever I visited her afterwards, the bandages having long since been discarded, I found her with her eyes closed, though not forced to do so by any aversion to the light; and laborious persuasion was needed before she would even come to look at the things immediately about her, and at last to become acquainted with them. Some years ago, indeed, her unfortunate father, who had hoped for so much from this operation, wrote that his daughter carefully shuts her eyes whenever she wishes to go about the house, especially when she comes to a staircase, and that she is never happier or more at ease than when, by closing her eyelids, she relapses into her former state of total blindness.

Of SCHNABEL I [33] it is reported a year later (three weeks after a second operation):

I discharged him three weeks after the iridectomy, by which time he had learnt to recognize all articles of furniture, clothing, eating utensils and the like, though I had not succeeded in awakening in him an urge to see, an interest in the visible. He did not look at those he talked with, and knew nobody. Had he not gone about without stumbling, it must have continued doubtful, even after hours of watching his behaviour, as to whether he was sensitive to light.

The state of pure sensation amounts, in effect, to a total absence of relationship among virtually all visual impressions. In this condition the stimuli received by the patient (apart from physiological limitations) are in all respects exactly the same as those of the normally sighted, but have, as yet, no spatial dimensions, either as to height or breadth. The elements initially presented to his mind constitute, at best, what Grafé describes as an '*arrangement en surface*', namely a fortuitously given ordering of various coloured patches, more or less indistinctly separated off one from another.

This state of being wholly unable to discern relationships, which in itself is undergone by all patients, is in most cases very soon terminated, in that, on first seeing, the newly sighted one is at once set a task by the doctor, whereby he is then forced into a perceptive frame of mind; though this, as already noted, remains unsuccessful at first, from a purely visual point of view.

2. Separation of Colour Patches; Perception of Movement

In passing from sensation to perception proper there is also, in many cases, an *intervening stage* to be observed, of which repeated intimations have already appeared, for example, in the cases of the first group (p. 107); it also emerges sporadically among the group of cases just dealt with (p. 129), who lingered for some time in the state of sensation, because they did not understand what they had to do, or did not respond to the task presented, and so also made slower progress in their development. This transition is marked by *separation* of the individual, sensorily presented *colour-patches* and preferential attention to one such patch, normally to that lying directly in the line of fixation.

The transition is commonly initiated by the occurrence of a change within the purely sensory order of colour-patches, owing to the *movement* of one of the patches belonging to this order.

UHTHOFF [54] exhibits this factor with particular clarity:

> On testing her eyes this morning (eight days after they were first opened), I was able for the first time to establish that our young patient sometimes follows a strikingly bright object (such as a sheet of white paper) by eye, once it is brought directly into her line of sight and then slowly shifted to one side. It can then be repeatedly confirmed, though not with any regularity as yet, that the child follows the object by eye, holding the head still and allowing the eyes to wander sideways along with the object.

The same experiment did not succeed, however, when the sideways movement was quicker, or when carried out only in the periphery of the visual field.

The newly sighted patient thereby gets his first clue that a specific meaning attaches to each of the various colour-patches belonging to the sensory order. He now for the first time guesses *what* he is supposed to see; he acquires an aim for his efforts at identification, and a corresponding inducement to examine these colour-patches separately; this being provided, in most cases, by the patch itself as it moves and thereby stands out from the rest.

The movement in question is not always grasped right away as 'movement'. LEPRINCE [63] provides an example:

> At this juncture, recognition of movement did not yet occur, and although, when one passed a hand or an object in front of his eyes and

said to him 'look, it's moving', he did his best to understand, he still did not succeed in grasping the meaning of the words. He took it purely as an interlude of light and darkness, without there being any awareness in his mind of a change of position.

In this case, for one thing, the field of vision was greatly restricted. Not only so, but in the darkened room, the sense-given field of colour-patches was in general very scanty, and offered virtually no major colour-contrasts beyond the whiteness of the hand against the dark background; and this the boy had already been possessed of before the operation. In this instance the eyes remain fixed in the same direction, and therefore apprehend only the change of brightness occurring there, just as before operation. One can very easily make this experiment for oneself by looking fixedly at a single point on the screen of a moving illuminated bulletin-board;* on confining the eye with some rigidity to this one point and endeavouring not to attend to the peripheral field, one experiences just this phenomenon of rapid alternation from light to dark at this point, without perceiving even the semblance of a movement.

Leprince's case is closely paralleled by that of MARC-MONNIER [38]: the doctor's hand describes a large cross, but the patient can neither follow its motion nor grasp a movement by eye; on hearing talk of motion he moves his own head to and fro, in the hope of perhaps gathering from this what the doctor wants him to do.

Thus the objective shifting of an image on the retina is by no means necessarily associated with an awareness of movement. But in the majority of cases, this first ocular perception of change within the sense-given visual field already produces a reflex attempt to follow the moving object by eye, as with Fischer (*cf.* p. 110). The movement has already been guessed or learnt to be such, though at first, no doubt, this is due, rather, to muscular sensations felt in the patient's own eyes during reflex tracking of a movement; or to changes in the background produced by the moving object; or finally, as with MOREAU [63]:

I see it move, because I hear it.

In a few cases only is movement already consciously grasped as such, in that the patients relate its individual phases one to another. While in no case is it recognized in virtue of a spatial conception of motion, pre-operatively acquired by means of touch. Thus, in Moreau's case, the patient is totally incapable of recognizing the visually presented motion

* i.e. of the type in which a message or picture is flashed in lights across the screen – Tr.

of a hand for what it is; Moreau finally allows his pupil to seize his moving hand, and immediately comes the cry 'in a voice of triumph: "It's moving" '; and here again the boy does not recognize the motion of the doctor's hand by eye, but in virtue of the muscular sensations felt as his own hand is carried along. This also shows once more that in executing a movement of his own the congenitally blind patient has absolutely no conception of space. The conscious apprehension of movement would itself already be an act of perception.

It is typical, therefore, of the transitional, or preliminary, stage of perception – whichever one chooses to call it – that the patient is beginning to get clear as to what he can direct his attention to when using his eyes. Again, the separation of individual colour-patches is not yet consciously performed at this stage, but first becomes available to him, as it were, as a possibility. It is still a sort of sensory and passive attitude towards the presented colour-field. The individual colour is not yet grasped in complete isolation, for it still forms only a part of the total field. The sensory image of a yellow matchbox on a brown plate has nothing in common with that of the same matchbox on a white plate, say, since the image is essentially altered. In the first case it is yellow on brown, and in the second, yellow on white. The yellow patch is not yet separated from its surroundings, and as the patient sees it, it still has nothing in the way of shape. Only a change in the total image, occurring under his eyes, or a hint from the doctor, leads him to a perceptual concern with this yellow patch, which he now guesses to represent an 'object' that he has already handled, and of which he knows that he would immediately recognize it by touch.

3. Perceptual Identification

Once he has grasped, therefore, what 'seeing' is, the whole thought of the patient in his subsequent attempts at vision is *directed to recognition of the visual object presented to his gaze*, partly through his own desire to know, and partly under pressure of the task assigned to him. Success is only possible, of course, on the assumption that sufficient time is allowed, during these first attempts, for symptoms of irritation to disappear. Since, however, the patient cannot recognize objects by purely visual means, he begins by at least trying to report what his residual vision had already supplied him even before the operation, namely the degree of brightness, and beyond that the colour, so far as it is already known to him.

A. PERCEPTION OF QUALITY ONLY (BRIGHTNESSS AND COLOUR)

As already seen with the first group, the earliest *reports* are all of *purely qualitative type* throughout; and questions about shapes go unanswered at first, because what the patients have understood by 'shape' when touching can give them no assistance in recognizing visual shape. In every case it appears that shape is something entirely alien to the patient, and as we shall subsequently confirm, it also remains for a long time unfamiliar and of no importance to his attention.

B. ASSISTANCE FROM OTHER SENSES: THE CONTRIBUTION OF TOUCH, HEARING AND SMELL IN IDENTIFYING OBJECTS

In this conflict between volition and incapacity, the patients now try to help themselves by calling upon all their *other senses to aid them*, and thereby seek out indirect methods of attaining their goal, to be able to designate visual objects by their correct names.

As to the sources of error so engendered, when assessing the visual achievements of the patients, MOREAU in particular has given a penetrating account of them and also provides a number of very apt examples from all the sensory fields. As a postcript to the above passage about the hearing of movement he adds:

> From the visual standpoint, this 'because I hear it' removes all value from his answer 'that's moving'. He perceived the motion by ear and not by eye. In this instance, indeed, he gave himself away; but how careful one must be in shutting out these sensory intrusions! This is a point which cannot be too closely attended to and in a number of observations it has been neglected. From the standpoint of the patient's visual education it certainly provides the best means of extending his powers of vision, but if one is desirous of verifying the quality of the sensations perceived, it is quite obvious that if the other senses are allowed to contribute they rob the experiment of a large part of its value.

As a number of our examples have already indicated, it is touch that plays the chief part here. There is not a single case to be found in which the newly sighted patient, as soon as he showed any interest at all in his new sense, did not immediately try to take hold of all the visual objects presented, in order to recognize them by the method he trusted. Herewith some further examples.

Thus HOME II [14] tells us:

> From this time [one day after the operation] he was constantly improving himself by looking at, and examining with his hands, everything within his reach.

WARDROP'S forty-six-year-old lady [16], who was certainly very disappointed (*cf.* p. 117) that she could not straightway transfer her tactual notions to her visual impressions, subsequently got into the way of systematically using touch and sight together.

> She seemed now to have become more cheerful, and she was very sanguine that she would find her newly acquired faculty of more use to her when she returned home, where everything was familiar to her.

This lady has therefore not yet abandoned the hope of still being able to apply her tactual experiences directly to her visual impressions; in her own familiar rooms at least, where, thanks to the schema that she has of the relative position of all the furniture, she knows in advance, according to this tactile ground-plan, what ought to be standing at any particular point when she looks straight at it. She thereby shows herself perfectly aware that tactual objects have not provided her with a proper idea of space, that it is only tactual qualities that help her to identify visual objects at once by name, and that she now has to acquire the true notion of shape from the very beginning by purely visual means.

MARC-MONNIER [38] observes:

> On wishing to become acquainted with an object, he touched it with his fingers, and after recognizing it in this manner, inspected it with care.

Thus 'recognition' by touch is confined entirely to discovering the correct designation of the object in question, in virtue of its tactual quality. RECORDON [20], for example, reports this of his fifteen-year-old boy:

> From this time on, K. saw something new every moment, but without ever knowing what it was until the object was described to him. This only applied, however, to things beyond his reach; for otherwise he knew things by touch as before, and so had knowledge of their names.

VON HIPPEL [23] set his child the task of seeking out by eye the nurse, who was standing motionless at one spot:

> The child opened her eyelids for a moment, rolled her eyes to and fro, immediately shut them again, and went round the room, now with her hands out, as though wholly blind, now bent rather forward, listening to the smallest sound, without at first finding the nurse. On finally reaching her neighbourhood, she stood still, stretched out a groping hand, felt that of the nurse, and immediately pronounced her name. Asked how she recognizes the nurse she answers: 'When I take her hand.'

Thus the child is seeking from the first to combine hearing and touch;

and what leads her to the goal is not touch alone, but also, no doubt, a sort of *perceptio facialis*, assuming that smells were not also involved here.

HIRSCHBERG [24] reports:

> It was evident that only with the assistance of touch-sensations would he easily and quickly succeed in converting his visual impressions into perceptions and ideas.

DUFOUR [26] shows his twenty-year-old male patient a square card and a round one, and also informs him that one is round and the other square:

> Noé remains silent for a moment and finally says that he cannot tell this. He then touches the square card first of all, and as soon as he feels one of its corners in his hand he says with an energy such as we had never found in his other answers 'this one is the square'. He then touched the round card, examined them both, and from that moment on has been able to distinguish rounded objects by visual sensation alone.

A pair of paper-scissors are then set before him, which he fails to recognize:

> I moved the scissors about, opening and shutting them. N. acknowledged the movement and said: 'It's shiny, it's like a knife, it's moving', but ventured no opinion. I drew his attention to the two rings designed to hold the fingers. He said: 'It's round.' But although he could see these two rings, and the two blades intersecting, he still declined to make any conjecture, though he was deliberating and also showed signs of genuine curiosity. I then allowed him to touch the scissors; he immediately put out his hand, felt one of the rings and at once said: 'It's a pair of scissors.'

Thus the young man had no spatial conception even of the scissors that he had used a hundred times, nor did the manipulation of them serve to remind him of his tactual schema. His accounts of his visual impressions are again purely qualitative; even the comparison to a knife is doubtless due, not to any quality of shape, but merely to resemblance in the metallic sheen.

FIALLA I 'does not recognize objects until she has touched them with her fingers'; so too with Fialla II, V and VI.

Of SCHMIDT-RIMPLER II [37] we are told:

> During the tests the child brought his eyes as close as possible to the things in order to see them, but could not name them; he tried to satisfy himself of their nature by touch. On recognizing them thus he took manifest delight in announcing their names.

GAYET'S sixteen-year-old girl [40]

> one day mistook an apple for a key, and a loaf for my hand, but corrected her statements as soon as we allowed her to touch the objects in question.

At a further trial she deliberates for a long time:

> After we had then given her our hand to touch, she stuck to her opinion and did not change it.

FISCHER [44] we have already quoted above (p. 110). In another passage he gives a further example:

> In the afternoon she is taken into the garden for the first time. She is greatly astonished, and can scarcely be persuaded to answer, stands speechless in front of the tree, which she only names on taking hold of it, and then as 'the tree with the lights in it'.

On feeling the spines, the nature of this tree also dawns on her.

Equally typical is VURPAS-EGGLI'S younger boy, aged four-and-a-half [53], who, like the five-year-old, had never arrived at any proper use of his sight.

> On presenting Jean with any article and asking him what it is, he at once lays hands on it; and if his hands are restrained, he gets close to the object, as though he would then have a better view of it, and applies his tongue to it. Only then is he able to give it a name.

Thus in all these cases we are concerned with purely auxiliary measures to which the patient feels impelled, and whose only purpose is to allow him to discover the correct name of the thing in question. They do not advance him much, however, in his task of recognizing the essential features of things by sight, and in particular make little contribution to his apprehension of shape. What he does gain from the procedure is the realization that 'this coloured somewhat' can be named 'such-and-such', and to that extent is something special to which he can direct his attention.

The sharp separation between the two *milieux* of the blind and the sighted is strongly felt by the patient himself, as is evidenced by the fact that many of them shut their eyes when seeking to identify visual objects by touch. We find this, for example, in AHLSTRÖM [51], whose nine-year-old girl could recognize nothing by eye, despite a previous period of tactual training:

> If allowed to touch these things with a finger, she immediately gave each of them their correct names. At the first trials it was strange to see how difficult it was for her to guide herself by sight and touch at once;

> if, after looking at the object for a time without being able to name it correctly, she was then allowed to touch it, she straightway shut her eyes or turned her face aside, and seemed to find it easier to apprehend the objects in this fashion than when she was simultaneously looking at them.

Now although these tactual movements made in identifying visual objects can easily be noted by the observer, and their significance allowed for, since they are taking place under his own eyes, the contribution of the patient's other senses is harder to control. In Part I we have already dealt in detail with the far more numerous – and in part actually quite different – ways in which the congenitally blind are able to make use of their auditory impressions; and there too we have already given some examples of how they are employed for purposes of orientation. Some further instances may be appended here of how the patient is post-operatively able to identify visual objects by their aid.

VON HIPPEL [23], from whom we have already just had an example in which hearing was involved, observes elsewhere:

> The child's unbelievably delicate hearing gave rise to repeated errors in determining the degree of vision she possessed; for if one made the slightest noise with an object brought into her neighbourhood, she at once recognized the thing without seeing it.

HOME II [14] was led into error by a sound familiar to him: on being allowed by the doctor to move around freely in the room, the boy heard a noise in the street,

> went to the window and called out 'What is that moving?' I asked him what he thought it was. He said: 'A dog drawing a wheelbarrow. There is one, two, three dogs drawing another. How very pretty!' These proved to be carts and horses on the road, which he saw from a two-pair-of-stairs window.

The boy had seemingly been misled by the reduced noise of the carts, owing to the height and the fact that the window was shut.

FRANZ'S patient [17]

> was not able . . . to recognize visitors, unless he heard them speak. . . .

So too with TRINCHINETTI [19]:

> Immediately afterward, her father, who had been present at the operation, stationed himself before her and asked her if she could see; the child's face became brighter than usual, and after a short pause she replied in her dialect: '*Vedi ol pa.*' On recognizing his voice she knew that what she saw before her must be her father.

In many cases (Hirschberg, Schnabel *et al.*) the clock is recognized by

its ticking and thereupon correctly designated as such. SCHNABEL [33] even made systematic use of auditory impressions, so that visual images should be more readily imprinted by association with them.

DUFOUR'S patient [26] was at first incapable of apprehending movement as such by eye, but then suddenly, without apparent transition, reported that people were moving about the room; Dufour himself supposes that he would have heard these people walking about and so knew that the gentlemen were moving, sought at once to follow them by eye, and thereby learnt how such an audible change of 'position' presented itself to the eye.

Here we may again take note of the very instructive experiment from GAYET [40]:

> I brought an uncle, of whom she was very fond, to sit by her bedside and told him to remain quite still; I stood behind him and told X to look at the face in front of her. 'That's your face,' she said at once. 'Reach out for it then,' I said. She stretched out her forefinger and ran it over a quite small surface of her uncle's cheek, and immediately her face beamed and she cried 'It's my uncle!'

Thus she orientates herself quite readily by the auditory impression, without giving any closer visual attention to Gayet's already familiar face, which she takes to be there because of his voice. In later tests also she is guided exclusively by her doctor's voice.

In FISCHER [44], the eight-year-old girl recognizes a rake from the sound of it scraping along the ground.

> A dog is brought into the garden, and the child led up to it: a new puzzle, whose solution is eagerly sought, but without success. The animal grows uneasy under her searching gaze, lets out a short growl and is now immediately recognized; the child exhibits the liveliest pleasure at this new discovery.

How loosely, even after weeks of experience, the visual shape-images often lodge as ideas in the memory, is very typically shown in the following example:

> A hen is let into the garden. As it stands there quietly, she does not know what it is. The creature runs off; 'It's the cat,' she says (with which she has been playing every day for nearly three weeks past, and always recognizes at once) – 'Well, go and catch her!' She runs in pursuit, but is by no means adroit at the business, and so harries the bird that it utters a few cackles of alarm. Half in disappointment, half gaily, she now cries out astonished: 'A hen!' only to go on chasing it with renewed enthusiasm. Once captured, she fingers it inquisitively and looks it over from every side.

Thus even by eye she only 'recognizes' the cat by certain qualitative features (grey colour) and not by any idea of shape, so that she confuses it with the hen, which was probably similar in colour. Alternatively, it was sufficient for her to see something moving low over the ground like this in order to venture an immediate judgement. Here too, a few noises are enough to correct her impression right away.

In like fashion she also recognizes her father and brother only on hearing their voices. VURPAS-EGGLI [52] report the same.

A similar experiment with a dog is recorded by RAEHLMANN [46]. Here again it is first recognized, not by touch, but from a growl. A bottle is identified on hearing the water lapping inside it.

After first declaring it a man, and then a cow, GETAZ [65] recognizes an animal by its grunting as a pig.

MOREAU [63] recognizes paper by the noise, and a moving wooden sphere by the sound of its rolling.

The following little episode is particularly characteristic:

> In the semi-darkness of a black-painted room, I stationed the assistant surgeon in one corner, wearing a long white overall half-open over a dark suit. In the other corner stood one of the sisters, his guardian angel, dressed entirely in white. I then sent young Henri out, with his hands tied behind him, from a position directly across the room, telling him 'Go to sister.'
>
> Communing with himself, he sets out towards the figure in white with a black vertical stripe, as exhibited by the assistant surgeon. He circles around him, without making touch with his head, and continually repeating in a sing-song voice 'That's not sister, that's not sister!' Then, observing the white figure of the sister in the other corner, he makes towards her, saying when he is quite close: 'That's sister. If I wait five minutes, she'll laugh.'

Moreau continues – and his words are of general application to all our cases:

> This answer seems to us typical, in that the help which the child expects and desires from his senses (in this case hearing), makes it absolutely necessary to proceed according to the rigorous method above described. If absolute silence had not been kept during this experiment, then, despite the fact that there could be no intervention from touch, this conclusive answer would not have been forthcoming, and a wholly erroneous inference would have been drawn from it.

Such a rigorous method would also require the prevention of all assistance from olfactory sensations. Otherwise it might occur to one that such impressions had contributed to the solution of the problem, since the boy went up so close to the two people that a slight whiff of

tobacco, for example, might have informed him that the first one investigated could not be the sister. His circulating round them indicates that he had probably noticed some particular visual feature peculiar to the sister, such as a gleaming metal cross on the chain of her order, which he failed to discover on the assistant surgeon, but immediately found on the sister; the information 'sister' would be thereby given schematically, without it ever occurring to him to look at the two faces, in which he would still have been quite unable to detect differences of form.

In many cases it is also sensations of smell which lead, intentionally or otherwise, to the correct naming of an object visually presented and apparently recognized by sight. SCHNABEL [33–34], for example, actually makes systematic use of these impressions also, by employing them to help in fixating visual images.

HIRSCHBERG'S patient [24] recognizes fruits by their smell.

FIALLA [31] reports of his fifth case:

> I noticed that he was not fixating the objects held before him. When I held his hands to prevent him taking hold of the objects he endeavoured to reach them with his nose or tongue.

UHTHOFF I [45] remarks quite generally:

> Inasmuch as he was in the habit of orientating himself concerning the object in question, generally by touch, sometimes by hearing or smell, and comparing the impression so obtained with that acquired by eye, he was obliged first to assemble his knowledge of each individual object.

Of LATTA'S case [60], we read:

> When he was shown a bunch of daffodils he recognized them by their smell, and immediately said they must be yellow.

LEPRINCE [63] writes:

> On being shown the inside of his shoe, he remarks 'It's yellow', and then, on perceiving the upper, 'It's black.' He approaches, smells it, and recognition follows.

MOREAU [63] was most fully aware of the significance of this sense as a much-appreciated aid in learning to see:

> It is becoming necessary to keep an ever more watchful eye on him. For he utilizes every conceivable means in order to recognize what is shown to him. Since he cannot use his hands, because they are tied, he smells at things and even tries to touch them with his nose.

This boy also recognized a bunch of flowers and an orange by their

scent. Moreau again alludes to Leprince's experiment with the shoe, and goes on:

> A few days earlier, on being shown a half-filled glass of wine, he says: 'There's wine in there, I can smell it.'

This same case of Moreau's is especially typical of just how natural it seems to the patients, when learning to see, to make use of all their other senses, and just how much of an actual torture they find it when, in the visual trials, they are systematically deprived of all other sensory assistance. Realizing the danger of falsifying the results, Moreau took special precautions:

> It goes without saying that all these and the following experiments took place in absolute silence. Apart from myself, only two other persons took part in these tests, the assistant surgeon and the senior sister. All assistance from olfactory sensations was likewise excluded. In order to ensure the purity of the experiments one has to be very careful about all extra-visual sensory aids. I only allow the intervention of another such sense when I consider it advisable to append a sensory confirmation.

It is all the more intelligible, therefore, when Moreau goes on to inform us:

> This result proving negative, he is then allowed to touch the proffered hand, and immediately gives a loud cry, if not of triumph, at least of deep satisfaction: 'The hand!' And his tone is no longer that of his previous tormented '*I* don't know.' The voice and face of the child are happy. His figure loses its cramped posture; he beams, laughs, repeatedly touches the hand with delight. This child with his lost brain has found himself again.

Here we already have evidence of a crisis undergone by nearly all the patients, and in many cases never again overcome, namely, of weariness at the exercise of vision. To this we shall be returning later.

It was important to go into the whole question of sensory aids, inasmuch as it shows how wary one must be of attributing something to the patient's vision when it has actually been accomplished by another sense. It thereby becomes clear that there is a positive duty to suspect a connection of this sort, even where no such relationship is evident at first sight; and also to have recourse to such auxiliary sources of knowledge when individual tests make it seem as though a visual shape has actually been recognized at first sight, on the strength of some discovered correspondence with a 'tactual shape' possessed before the operation.

This becomes no less obvious on entering still further into the course

of the visual learning-process. We shall see that it is only at a relatively late stage that shape begins to take on significance in the patient's imagery.

C. COLOUR DECISIVE IN THE IDENTIFICATION OF OBJECTS: RECOLLECTION OF, AND PLEASURE IN, COLOUR

Now when the patient has thus discovered the significance and names of visual objects by making use of his other senses, he has not thereby accomplished anything more than he was also accustomed to doing before the operation; above all, he has not yet by any means assimilated the element of shape in their appearance. We have already had abundant evidence, from all the cases so far cited, that at first it is only the purely qualitative factors that matter, and are observable, to the newly sighted one, namely colour and brightness. So far as he is not actually dazzled by it, brightness, to him, is not so much an intensity as a quality. Colour he has commonly had no acquaintance with at all, before the operation, and has not yet normally assimilated it sufficiently thereafter to be able to distinguish it with certainty. And since often the visual objects first presented each have a different colour clearly distinguishable from the others, it is sufficient for him to see a particular colour in order to be able to *give a correct name to the thing that has this colour*, without his having the least notion of its shape. Herewith some examples: a sixteen-year-old patient treated by BEER [10] only recognizes his father from among a larger group of people when he has his red coat on. More typical, however, is another of Beer's cases (a fourteen-year-old girl): Beer used for his test a hat and a man's shoe of the same colour. The girl could naturally distinguish these at once by touch, even when she merely tapped them with a finger, so that eventually the impression arose that she could already distinguish both of them also by vision alone. It turned out, however, that on touching them she had also noted the relative positions of the two objects, so that she therefore knew which object was the source of the right- or left-hand visual impressions appearing to her.

> For although she had also at this moment distinguished them precisely from one another by touch, I had only to change their places quickly, and she could no longer tell which of the two was the hat, until I finally pointed out to her the difference of outline and the whole form of the two objects. In general, I have observed throughout that resemblance of colours throws these patients into the greatest confusion.

Shape was therefore of no importance whatever to her, either in

touching or looking, nor did it in any way obtrude upon her sight; in both cases, rather, she attended exclusively to the qualitative impressions, different to the touch, but the same to the eye, and had first to have her attention drawn to the fact that shape is an essential criterion of difference among visual objects.

WARDROP [16] remarks, in his final summary, that his forty-six-year-old woman patient responded to colour, but that

> She had as yet acquired, by the use of her sight, but very little knowledge of any forms, and was unable to apply the information gained by this new sense, and to compare it with what she had been accustomed to acquire by her sense of touch.

Nor could it have been otherwise. For although things may have a variety of qualities, so that a tumbler, for example, can be recognized via quite different impressions from three distinct senses, they still have only one shape; and when, in learning to see, it emerges that this shape is something entirely unknown and novel to the learner, he thereby gives evidence that even beforehand he had had no spatial awareness of shape proper.

So too with HIRSCHBERG [24],

> he was astonished by all these objects, looked at them very attentively and gave the colours with great correctness. But he could not describe the shape.

In DUFOUR [26]

> the young man accurately reports the blue colour of a cravat worn by the attendant, but without concern for anything else but the colour, since the form of the object is still unknown to him. Nor does it seem that, while immersed in contemplation of the blue cravat, his attention was attracted either to the face or body of the person wearing it.

SCHNABEL'S boy [33]

> was very quick in learning to recognize colours. After having once shown him a number of samples of coloured paper and told him the names of the colours, he never made a mistake in naming them, even when I only showed him the coloured sheet for a moment.

In this case, for want of interest and practice, there had been no change of condition when the boy was brought to Schnabel for a subsequent operation, eleven months after the first:

> Not only has he not enlarged his knowledge of the visible world; he has even forgotten again a number of objects that he had learnt to recognize during his first stay at the clinic. Only his knowledge of colours has been strengthened and increased.

Of his twelve-year-old girl [34], Schnabel says:

> The patient showed most certainty in describing the colour of presented pieces of paper, and although she could with difficulty determine the outline of a flat object, colour was a much more important feature to her than form, so that she described, e.g. a silver sixpenny piece as a florin, while she took the much larger copper penny piece for a farthing.

FISCHER's girl [44] distinguishes her nurse by her large white apron, and can only point out the colours of her doll. In the course of other tests her own blue drinking-mug was repeatedly held out to her and named, and this she eventually recognized again, probably from its blue colour.

On the fourth day she was already sometimes producing the correct piece of fruit from her lap,

> but seems to decide upon the object chiefly by colour. The pears are all green, the apples red, the plums blue, and selected according to the same relative sizes as the day before. But instead of an apple, she brings out a pear of half the size, then compares the two, probably as to colour, sees that they are not alike, and starts searching anew.

In her first picture-book, too, she was plainly interested only in the colours:

> for while she points correctly to the yellow chick, she completely misses another one painted a greyish yellow.

SEYDEL's ten-year-old girl [58]

> learns a few more objects by rote each time, from one lesson to another. To begin with, she chiefly remembered them by their colours.

This naturally tended to produce extraordinary mistakes. Thus

> on the fourth day she mistook a matchbox for an apple, which she had learnt to recognize on the previous day, through taking her cue from the red and yellow colours of the apple, which also appeared on the matchbox.

LEPRINCE [63] reports:

> The boy was very quick in learning to recognize colours, and thereafter made use of this knowledge in order to define objects more accurately by reference to their qualities. His mug: 'That's something white and something black, it's a light', then 'it's a saucepan', and finally, 'it's my mug'.

Moreau's account of the test is as follows:

> He calls his tin mug white and black, and when pressed for a more exact answer replies 'It's a light.' – The reflection from this glistening

> object perplexes him at first; he relapses into his original manner of seeing, and his words 'It's a light' correspond to the 'that's shiny' of his previous phase, before he yet had a notion of colours. After a moment he says 'It's black and white', 'it's a pan' and finally he ends by crying 'Oh no, of course it's my mug.'

More than a year later, on seeking out his patient again in his mountain village, Moreau is obliged to admit:

> He no longer has the ideas of round and square. On showing him the corner of a cube, he cannot describe it, which he formerly could. Throughout the whole visit he did not recognize the cube. Colour-patches, on the other hand, are accurately described.

The patients are, indeed, much inclined to neglect shape in favour of colour; they are influenced, moreover, not only by the individual colour of the object, but by the whole coloured visual field, in other words by object plus environment, figure plus ground; and their judgement is primarily based on this purely colourful, pictorial impression, without abstraction of any sort of element of shape from these visual images. All this comes out especially in the fact that altered experimental conditions, particularly the choice of other colours, immediately lead them astray and confront them with an enigma.

Thus HOME I [13] reports:

> When the four corners of a white card were pointed out, and he had examined them, he seemed to know them; but when the opposite surface of the same card, which was yellow, was placed before him, he could not tell whether it had corners or not, so that he had not acquired any correct knowledge of them, since he could not apply it to the next coloured surface, whose form was exactly the same with that, the outline of which the eye had just been taught to trace. . . .

HIRSCHBERG [24] tells us:

> Nor did he know again a gold ring with which I had acquainted him on the day previous. After he had again familiarized himself with its appearance and I had set out the features of a gold ring to him in a way he could understand (yellow colour, rounded edge and the hole punched in the middle), he still could not recognize as such a second ring, of somewhat different shape and set with a stone.

As compared, therefore, with the difference in pictorial impression, the similarity of shape had no effect at all on the resultant interpretation.

FISCHER'S eight-year-old girl [44] had got to know her first picture-book well and truly, up to the twenty-second day.

> She is now given a second picture-book, containing the same animals as the first, only depicted by ones and twos in somewhat different

> shades and postures. Here she recognizes the creatures no longer, but points triumphantly to a donkey and its long ears and says: 'That's a rabbit.' In the end she tearfully declares that it is not a nice picture-book at all.

Here we already have a certain transition towards attempting, just as with touch, to create a foothold, a schema, for shape. Thus 'long ears' means a rabbit. One may also observe something of the kind in children, when they take note, in animals, only of shape-characteristics quite grossly deviating from the norm, or of the noises made by them, and maintain the two together, name and properties, in a sort of association, so that one is inseparable from the other. We shall encounter a considerable number of further examples of such after-effects of the urge to form a schema.

UHTHOFF also provides a series of examples of the influence of variation in the test-conditions: thus, right at the beginning of visual testing, his first case was presented with a matchbox, and was allowed to see it repeatedly for a week, but only from in front, with the label showing, so that he soon recognized it quite readily. When the box was then suddenly shown him for the first time from the rear, which was blue and unlabelled,

> he failed to recognize it, nor did he do so when it was presented to him sideways on. . . . A similar observation could be made with a red Swedish matchstick with a yellow head; he continually recognized it with confidence, but when, after a longer interval, he was shown a white Swedish match with a black head, he did not know what it was.
>
> Again, if objects already extremely well-known to him by experience (e.g. an egg, a potato, a lump of sugar), which he readily recognized by sight alone, and had often seen, were shown to him in the coloured beams of a solar spectrum, he no longer knew them; but if they were then removed, before his eyes, from the coloured light, so that they were no longer illuminated in colour, he at once identified them correctly again.
>
> When I showed him, for example, a white lump of sugar in my hand, or laid it on the table in front of him, it was promptly recognized; if I then tied it to a thin black thread and let it dangle in front of his eyes, he at first failed to recognize it.
>
> Similar objects also, when presented in a different colour or form, were often wrongly described. Thus he had long been able to recognize, e.g. a cane-bottomed wooden chair by sight; but when, some weeks later, I took him somewhere quite new to him and showed him for the first time a dark-brown leather-covered chair, he did not know what it was.
>
> A shining silvery pin he could almost invariably tell correctly at once, and in course of observation it had often been shown to him. Four

weeks after the start of visual testing he was confronted for the first time with a black pin, with a rather larger black head, and failed to recognize it.

Similar errors may also occur when the objects themselves are left unchanged, but are shown against a different background.

Thus SEYDEL [58] writes:

> Environmental changes were liable to confuse her completely. Thus if objects were no longer held in the hand, as usual, but laid on the table, she hardly recognized them at all.

In recognizing people

> she based her judgement on quite gross external features, such as a white apron or an eyeshade. Even a month later there was no evidence of any real progress, save only that she had become rather quicker and more certain in her judgement; and even so, changes in these external conditions immediately led her astray.

These examples already show that after a short time the patients readily retain a memory of colours and can also readily compare them, no matter whether the colour for comparison is itself given by eye, or merely possessed in imagination.

Thus in WARDROP II [16] the patient asks the mistress of the house what the colour of her gown is, to which she is answered that it is blue.

> 'So is that thing on your head,' she then observed, which was the case; 'and your handkerchief, that is a different colour', which was also correct. . . .
>
> When at tea she took notice of the tray, observed the shining of the japan-work, and asked 'what the colour was round the edge?' She was told that it was yellow, upon which she remarked, 'I will know that again.'

FIALLA V [31]

> could not name colours; when shown a white coat and asked the colour, he replied with a comparison, that it was the same colour as a shirt; of red objects, he said that they were the colour of fire.

MINER [54] found a quite unusual sensitivity to colour in his twenty-two-year-old girl:

> She can detect color in solutions that are perfectly transparent to those of us who have been working with her in the laboratory. She can also discriminate differences in tint which are considerably below our threshold. In looking at the spectrum, she can apparently see ultra-violet, which is beyond the usual field of view. . . . Preliminary work with the spectroscope indicates that her spectrum is about one fifth

longer than the average of ten students. The length is added at the violet end.

To account for this phenomenon, he envisages three possibilities:

The lens may obstruct our view of color, the color process may deteriorate with age, or a phenomenal interest in color may increase our liminal and differential sensitivity for light far above the average

One of LEPRINCE'S experiments also bears on this point:

The testing of his night vision revealed a very remarkable association of ideas. The reflection of the electric torch on the balcony during a cold night produced in him a sensation identical with that of the sun's reflection on snow, as he had perceived it before the operation, and he cried out: 'Oh! What a lot of snow there is to-day!' This sensation of whiteness is in fact common to all operated cataract patients, and it is one of the commonest remarks they make after the operation, the reason being that, in its normal condition, the lens absorbs the greater part of the ultra-violet radiation.

LATTA'S young man [60] had no notion of colours before the operation, but as a gardener he was familiar with all his flowers by touch and knew what colours they were. After the operation he now taught himself all these colours from flowers which he recognized by scent or touch.

This universal partiality among the patients for the colours they have so long had to forgo, is already proof that in seeing they apprehend actual hues of colour, and do not merely differentiate them, as it were, by light-intensity. It is from colours that they first derive real pleasure when learning to see; as is also shown by the way in which many patients very soon develop a passionate enthusiasm for certain favourite colours. MOREAU [63] is the sole investigator who attempts to determine the colour-quality of visual impressions by experiment, in that at each colour test he first gave his boy black and white cards and only then went over to coloured sheets.

He first recognized light and dark, commonly calling them black and white, and later the colours. . . . On the 5th September, when out for a walk with the sister in the hospital grounds, he pointed to the turf and said: 'That's a field, it's green.' 'How do fields look to you?' – 'They're white.' – Before his operation the boy had had notions of light and darkness only, and since of course, he had only wandered by day in the pastures at home, the reflection of daylight on the green herbage had imprinted an image of brightness or whiteness on his retina. Vivid colours appeared to him as something bright, the sombre ones as something dark. He has now learnt to see, to distinguish and to name colours, without regard to the light-intensity reflected from them. Up

till then he had described objects merely by saying 'That's shiny', but now he describes them by their colours.

We cannot, indeed, point to a single instance in which the patient is said to have been baffled by colours when learning to see; though there are many who never succeeded in apprehending shape.

Before embarking further upon this process of learning to see shape, let us remind ourselves again of the stage it has already reached, so far as shape enters the question.

Thus the patient has noted that the initial gaudy confusion of colours does in fact manifest an order, and has observed individual colour-patches in isolation. But since colour was something new to him, it has so far been unable to help him in the recognition of visual objects. What he had hitherto gathered about shape by touch has been of equally little help to him; for although the use of all sorts of schematic aids in the touching-process has enabled him to say certain things about shape, as it appears to the sighted, he has not been able to abstract from this process any closed, simultaneous idea of spatial shape, such as he might have been able to transfer to visual shape. He has therefore tried to help himself by calling upon his other senses – touch, hearing, smell and taste – for the general purpose of first identifying even the names of visual objects. The impression which affects him most strongly in this is that of colour. It is colour of which he most readily retains an image; it represents, for him, the major point of distinction between objects, and for long remains the sole clue to re-recognition of the small number of objects first shown to him; whereas all questions as to shape he is obliged to leave unanswered, since at first they simply convey no meaning to him. By and large he is still, as it were, swimming in colours, without yet being able to fit them all together in his mind in proper order, and without knowing more of them than that all these colours belong to some coloured thing.

III

DEVELOPMENT OF SHAPE-PERCEPTION PROPER

1. Review of Results already Obtained from Visual Learning; the Development of the Organ of Vision

During this first period the patient is normally confined to his sickroom, or at best to a number of relatively similar rooms in a hospital, in which, for the most part, he has also had some opportunity of orientating himself as to the contents, before the operation. He thus already possesses a comparatively well-developed schema of the rooms in which his first visual studies are carried out. And this, as we have been able to show in a number of cases, gives him a clue as to which objects must be situated in this or that direction from his bed. Thus, for the patient who really wishes to see, and enjoys doing so, the task so far has not been particularly difficult. For since he does not find a great many objects in his sickroom, he manages pretty well at first by distinguishing their colours. He also has sufficient leisure to investigate by touch such objects as attract his attention in any way, and then to make his visual studies on that basis. If he is interested, he will also very soon express a spontaneous desire to be shown objects (such as a watch, for example) which he had already wished he could see before the operation.

Up to a point, therefore, he sets the tempo of his education himself, and so things often go relatively smoothly at the outset, so far as there are no post-operative reactions present to limit his desire for knowledge, or impair his pleasure in his own visual experiences. Since he still considers colour to be the essential feature of things, and also manages with this at first, in the narrow confines of his environment, he is as yet very imperfectly acquainted with his task, and is not yet rendered uneasy by knowledge of it, or by a bewildering wealth of visual impressions.

This state is also very well adapted to that of his eyes after operation,

since their motor apparatus only gradually takes on its appointed functions once the eyes are in use. Colour, however, is what he always recognizes, despite the persistence of nystagmus. But he generally looks so closely at the middle of the colour-patch, that the wobbling of the outline does not distract him greatly, because it already falls on the peripheral areas of the retina, whose impressions he either does not perceive at all, because of the limitations of his visual field, or has not yet learned to detect and evaluate; whereas colour is more or less uniformly suffused over the whole sensitive area of the visual field. But that these particular physiological conditions are not just the only reason why the patient cannot report on the shape of his first visual objects, is something we shall soon discover, from examination of cases in which these physiological circumstances do not apply.

2. Recognition of the Task. Crisis in Learning. Influence of Affective Participation on the Learning-Process

In the natural course of events, we soon reach a point where the visual range and problems of the patient have so far grown upon him that he realizes that he cannot make do with this distinguishing-mark of colour, since too many objects have the same colour. He begins to recognize that, in order to make any sort of worthwhile use of his sight, he has got to concern himself with the shape of things, so as to be able to distinguish objects of identical colour.

It is now that he first embarks properly on the true process of learning, at a time when his initial curiosity is already sated. And here there commonly begins a *crisis*, which is undergone by all save a very few patients, such as those of Latta and Grafé, for instance, whose will-power is already fully engaged and sufficient to keep them going. The time of onset of this crisis may vary, but it normally starts at the very moment when the patient realizes that the success of the operation has not just simply given him the ability to recognize visual objects, and that it is he himself, rather, who must seriously and steadily apply himself to this end.

A crisis of this type is more or less readily observable in all learning-processes, namely when after initial good progress a sort of hold-up occurs, in which the first charm of novelty is lost and is succeeded by a certain distaste and weariness. This hold-up is overcome only upon the exertion of conscious and tenacious will-power.

Now this crisis is bound to fall particularly heavily on the once-blind

patient, because in his case there are nearly always a number of concurrent reasons, any one of which would already be sufficient to imbue the learner with a certain distaste. The physiological reasons have already been briefly touched on, namely nystagmus, and maybe strabismus as well. Given a serious determination to see, however, these two factors are normally quite soon overcome, since on using the eyes the nystagmus tends increasingly to disappear, while in a non-operated strabismus the visual impressions of the divergent eye are soon disregarded and are not perceptually evaluated. At all events, there is scarcely a case among our material in which the process of learning to see was frustrated for either of these two reasons, unless there were other contributory causes of a psychological nature; though the latter may well have been partially occasioned thereby.

More important, because more persistent in their effect and therefore harder to overcome, are the internal, psychological reasons for this disgust. On emerging from the narrow confines of the sickroom, in which he has become tactually-and-visually at home, the newly sighted person is swamped by an immense wealth of visual impressions; or objects are shown to him, during the hours of systematic instruction, to which he is emotionally indifferent. Whereas, as a blind man, before the operation, he was in danger of being mentally and spiritually stunted for want of impressions, the opposite is now the case; he can no longer shield himself from a constant flow of new impressions, and impressions, moreover, which all arrive simultaneously, whereas previously his perceptions all occurred in succession. At the outset he is quite helpless in face of all these novel impressions, without having even an inkling as to what is immediately important to him and what he is not so much in need of just yet. He is asked so many questions that he cannot answer, and finds so few points of attachment from his previous sphere, and can only arrive at knowledge by roundabout means. To this is added the realization that he has got to work out all these visual matters once and for all, and as quickly as possible, because he is now regarded as a sighted person, and will soon be called upon to do something useful, for which he will have to make use of his sight. He acquires a vague conception of the enormous task that lies before him.

These three factors, the abundance of impressions, the awareness of the size and difficulty of the task and thirdly a sense of being under pressure, of having to learn, all bear especially hardly on the patients, because in the majority of cases they are manifestly weak personalities; once confronted with the wealth of impressions they become sensitive,

irritable and very easily fatigued; they also show little development of will-power, so that their efforts of will quickly peter out.

All this makes it intelligible that, once the patient has made a few systematic attempts to practise his vision, and has found, in doing so, how difficult it is for him to master shape, his previous condition should then appear to him the more agreeable of the two. What was previously an intolerable shortcoming – assuming he was capable of feeling his condition to be such – now appears to him as a blessed state of peace, a haven of security, with respect both to the sensory aspect and also to the simplicity of his duties in daily life.

It should be noted at this point that the patients we are dealing with are for the most part not comparable with the inmates of our blind institutions, in regard either to their intellectual training, or to the development of their sensory capacities. A section of them may be safely described as people who had been simply overlooked, as it were, in the matter of operation and education, and had vegetated without proper mental or spiritual care; such, for example, were the patients of Vurpas-Eggli, Moreau and others, who had not suffered in the slightest from their disability, because they knew no other state of existence. Among such cases, it is obviously not to be wondered at if their stupidity emerges as an insurmountable obstacle to the doctor or psychologist, because there is simply nothing there on which visual training can be built, and because nothing serves to awaken these patients from their lethargy.

But even among those who by training and occupation may be ranked as intelligent blind people, and who really wished to see, this crisis very often occurs, and vents itself in ill-temper, or again in a sort of passive resistance.

The result is normally that the continued reliance on the familiar use of touch, which initially lasts for some time, owing to the need for orientation, or merely out of habit, then easily becomes a deliberate policy of barring-out the visual world, whether from satiation with visual impressions, despondency, indolence, or dread of later obligations. This occurs even when the visual experiences already present are by now objectively and subjectively quite sufficient to guarantee the certainty of visual orientation, as, for example, in the case of DUFOUR [26].

Probably the most difficult task ever accomplished by a doctor on one of these patients – and in every respect a model – was that undertaken by MOREAU [63]; he was first driven to the conclusion that his eight-year-old patient was an idiot, but then set himself, over a period of fully

eighteen months, to turn the boy into a useful human being. But then, a year later, having had to give him up, owing to quarrels with the parents, to a child welfare establishment, he was left to discover how all that he had instilled into the child by way of education had again been lost. We can therefore appreciate the justice of his words when he writes:

> It would be an error to suppose that a patient whose sight has been restored to him by surgical intervention can thereafter see the external world. The eyes have certainly obtained the power to see, but the employment of this power, which as a whole constitutes the act of seeing, still has to be acquired from the very beginning. The operation itself has no more value than that of preparing the eyes to see; education is the most important factor. The occipital lobes can only register and preserve the visual impressions after a process of learning and after methodically administered practice. To give back his sight to a congenitally blind patient is more the work of an educationist than that of a surgeon.

The particular occasions of crisis in each case naturally indicate also the individual pedagogic measures to be applied. The aim in every case will always be the same, namely, to endeavour that the patient shall overcome this crisis as soon as possible, shall acquire confidence in the learning-process and from then on shall become emotionally attached to it in the strongest possible degree. For at the very moment when the patient reaches this point, he has himself taken his further education in hand, and himself knows best what he lacks and how to obtain it; he then proceeds in the same way as all children, only more quickly and deliberately. As to how the various teachers of the patients have helped them in such a crisis, we shall learn, in some cases, when we come to discuss the further stages of the learning-process. But first let us give some examples of the condition itself and its various manifestations and causes.

A condition of satiation naturally occurs most readily in those who before operation had hardly perceived even brightness, let alone anything coloured. MESMER [9] gives us an example of this:

> In her ill-humour she once complained to her father: 'How comes it that I now find myself less happy than before? Everything that I see causes me a disagreeable emotion. Oh, I was much more at ease in my blindness!' The father consoled his daughter with the thought that her present agitation was solely due to the sensation of strangeness in the sphere she was now moving in. The new situation she found herself plunged into by the recovery of her sight must necessarily awaken in her an uneasiness never felt before. She would, however, become as

calm and contented as others, as soon as she had grown more accustomed to seeing. 'I am glad to hear it,' she replied, 'for if I were always to feel such uneasiness as I do at present at the sight of new things, I would sooner return on the spot to my former blindness.'

This wish of hers was granted, for after a time she again went blind and subsequently made a name for herself in the blind welfare work of the day.

BEER [10] writes:

> Among the most remarkable psychological phenomena presented to my observation in all the patients so far operated upon, is the rapid and complete loss of that striking and wonderful serenity which is characteristic only of those who have never yet seen; for hardly are the first lively sallies of their curiosity satisfied after the operation, than already they evince this striking transformation of their attitude. Gloomy and reserved, they now shun for a time the society of others, which was so indispensable to them while they were blind that they lamented every moment they were obliged to spend without it.

Beer has also given thought to the reasons for this:

> Might not the reason for this sudden and striking change of temper, indeed I might say of the whole character, be partly due, perhaps, to the fact that the patients have supposed all objects, which they could only get to know by feeling when blind, to be quite different from what they subsequently see them to be; and might not also even a sort of injured pride contribute something to this transformation, in that they now suddenly find themselves so far behind other people of their age, even in the most trivial matters of knowledge? I fancy that in some at least, I have found traces of such a thing.

This, indeed, is what we have described as despondency on recognizing the difficulty of the task. One of Beer's cases, though to be sure it was a matter of pure laziness and shirking, has already been cited above (p. 135), as also the disappointed despondency of WARDROP II [16] (p. 117), which was not yet quite overcome even six weeks after the operation:

> She still entertained however the same hope which she expressed soon after the operation, that when she got home her knowledge of external things would be more accurate and intelligible, and that when she came to look at those objects which had been so long familiar to her touch, the confusion which the multiplicity of external objects now caused, would in a great measure subside.

The despondency was intelligible in this case, because from the beginning she had been so much left to her own devices, without anything that could possibly be described as methodical guidance in learning to see. She continually encourages herself, and hopes, by starting

from the tactual objects known to her, herself to systematize her visual education. What disturbs her is, once again, the superabundance of unknown impressions. Only her self-confidence and endurance of will prevent her from losing heart.

Profound satiety and weariness were also experienced by FRANZ'S eighteen-year-old young man [17]:

> Although the newly-acquired sense afforded him many pleasures, the great number of strange and extraordinary sights was often disagreeable and wearisome to him. He said that he saw too much novelty which he could not comprehend; and, even though he could see both near and remote objects very well, he would nevertheless continually have recourse to the use of the sense of touch.

In this case also, the condition lasted for some time:

> Walking alone in the crowded streets, especially in the City, he found very tedious. He said, seeing so many different things, and the quick movements of the multitude of people, carriages, etc., confused his sight to such a degree, that at last he could see nothing; that the sensation produced by the object last seen had not yet disappeared from the retina, when the next object made its impression thereon, by which means confusion of ideas, great anxiety, and even vertigo were occasioned, from which he could only free himself by closing his eyes for a few moments.

In VON HIPPEL'S case [23] it was the numerous operations which led to a crisis, though the little girl subsequently overcame it:

> I must say a few words about the favourable change in the state of mind of our little patient, which became strikingly evident after the last operation; whereas from the first operation onwards she had been ill-tempered at all the visual trials, she now seemed constantly cheerful and rejoiced at every correct answer that she gave, without crying, as before, when she made mistakes. It seemed that with the increasing improvement in her sight her joy at her newly-acquired sense had begun.

SCHNABEL [34] writes, four weeks after the beginning of visual testing:

> In the meantime, a very striking change has come over the child's state of mind; the visual curiosity and joyful hope with which she approached the first visual tests are equalled only by the peevishness with which she now obeys instructions to look at an object.

The reason in this case was partly disappointment at the limited acuity of vision, but partly also a liability to rapid fatigue:

> But the more often I showed her the mirror during the visual tests, the

less interest she showed towards it, and finally to this object she displayed the same peevish indifference that she lapsed into every time she was asked to look at something.

Since, in her case, it took ten months before her sight developed into a usable power of vision, the crisis here also lasted a very long time, so that three months after the operation it is still the case that:

She therefore made as little attempt as the boy mentioned earlier to look at anything outside the hours of practice, and lost all her good-humour as soon as she was compelled to see.

But since the girl then made good progress at home, it may be assumed that in this case her ill-humour was also a product of homesickness; unless one is to infer from the fact that two successive cases had miscarried, that the stern methods employed on the two children had disheartened them. For it appears without doubt, from a whole series of cases, that the will to see, and courage and cheerfulness in the atttempt, have a very strong effect upon the rapid development and improvement of the physiological adjuncts of vision. It is important, therefore, even when the power of vision is relatively weak, to enhance the will to see, and not to give up the trials prematurely, in view of this poor visual capacity and the despondency of the patient which is eventually liable to result. For if the visual organ is not used, there is no possibility of improving the power to see.

SCHMIDT-RIMPLER [37] reports:

With this boy also it appeared, as in other cases, that the first visual tests definitely gave him more enjoyment than the later ones, where he had to learn. When he had finally named a series of objects shown to him, he turned away gladly with the words 'Now I have said it all', content to have the lesson behind him. But he differed from many other blind patients, who later learned to see, by the fact that he always kept his eyes open and continually made use of them.

Now in this case it would have been of great interest to have the continuation of the report and an account of the degree of vision attained. But the promised sequel has not appeared, nor could it be obtained from Marburg.

Schmidt-Rimpler also gives only a very summary account of his first case [36]:

This child continued to keep her eyes shut for weeks, when going about, and attempted to guide herself by touch, although experiments showed that she saw quite adequately with the eye operated on. Only later did she learn to use her eyes.

ALBERTOTTI [39] did not succeed in overcoming this crisis, although before the operation his young man had cooperated very eagerly in all experiments.

> One had continually to lead his attention back to what he was seeing: he would not trouble to make use of the visual sensations he received. Left to himself he actually fell back, after some months, into his earlier pitiable condition before the operation, ever more disillusioned in his hopes.

Albertotti himself writes:

> When I realized that I had not been wholly equal to my task, I was too late.

It is certainly understandable that the young man should have brought no enthusiasm to his task of seeing, after he had first spent another twenty days in bed after the operation, then gone about for a further month with eyes bandaged, apart from the experiments, and had had to undergo even the experiments themselves in a dark room, using one eye at a time. In such cases, all other considerations and scientific desiderata must obviously be subordinated to pedagogical needs.

In GAYET [40] we read:

> She obviously found the untried experience of seeing somewhat disturbing; and how gladly did she receive permission to close her eyes, or at least let them relapse into their natural fixity, and to assist herself by touch!

UHTHOFF [45] had great difficulty with his first case, a seven-year-old boy, because here it was necessary actually to awaken him mentally in the first place.

> Both before the operations, and even after them, he was liable, when left to himself, to remain quite quietly in one spot, and to stand for hours in a particular place.

Uhthoff then reports also, of the first visual tests, that

> patient was very apathetic at first towards his gradually unfolding sense, and did absolutely nothing on his own initiative about learning to see.

Later too, we learn:

> This attitude of the patient has remained entirely unchanged during the first fourteen days, especially when he is left to himself; and even much later, when the tests have been going on for a number of weeks, and when the patient has already had many experiences and knows many objects, he continues at times, when left to himself, to exhibit a very similar attitude.

It is therefore easily understood when Uhthoff says:

> His initial complete indifference to his newly-won vision has often made visual testing a very time-consuming affair, and one calling for a great deal of patience; in the first phase it was often a matter of many hours of daily formal instruction in order to make progress with the boy on the various visual tests, and often to initiate him into a series of concepts.

It then became possible, however, from time to time at least, to awaken his interest for a little and thereby to secure his own cooperation:

> For more than an hour this child, who is normally so apathetic, displays the greatest interest in his counterpart in the mirror, calls to him, speaks to him, tries to lay hold of him and so on.

Thus in this case the secret consisted in so organizing the visual tests that they appealed to the child's play-instinct, continually varying the experiments in order to keep on reviving his interest and thereby his cooperation.

> It took a full week before the child began to show a more truly lively interest in the visual trials. Indeed, a real change in his whole mental attitude was not discernible until some two months after the beginning of the tests. Until then it often took energetic admonition merely to attract his general notice, even when direct trouble was impending, due to his own inattention.

In GRAFÉ [49] the initial indifference towards visual impressions is attributed to excitement, confusion, dazzlement, irritation and nystagmus. But this is improbable, because as BRIBOSIA [49] reports, this boy had himself taken the initiative over his operation, and also displayed thereafter a strong desire for knowledge and delight in colours. In this case there may well have been no crisis, in our sense, for he really had no difficulties in learning to see. Grafé himself opines, in another passage:

> It may also be that this calm and insensitive attitude merely lay on the surface, and that inwardly he did react to the phenomena, although lack of experience, the awkwardness of his speech (dialect), or even fear, prevented him from giving expression to it. One had, as it were, actually to drag the intimacy of his thoughts and feelings out of him.

VURPAS-EGGLI [52] were

> frankly astonished at the little joy they displayed at having received their sight.
>
> It is quite obvious that the boy refuses to make any intellectual effort to follow the questioner.

These two cases were clearly feeble-minded, as can be gathered, not only from the passages quoted on p. 134, but also from the following:

> Jean is constantly forgetting what he has done or what he has in his hands, in order to turn quite abruptly to something else. Having received a bun, for example, with genuine pleasure, he holds it quite mechanically in his hand and amuses himself with something else, and one has actually to remind him that he has a bun that he is supposed to eat.

A similar case of feeble-mindedness is exhibited in LATTA II [61]. Whereas the thirty-year-old brother (Latta I) learned to see with complete success, his thirty-three-year-old sister could not be brought to do so:

> The deficiency in her intelligence and interest, and her tendency to relapse into the world of the blind, seems to me to arise from the narrowness and the mechanical character of her practical life. Her sight is of little use to her because she has few practical interests, and those she has can be quite well satisfied in the blind state. Her experience is too thoroughly stunted to grow under the new conditions.

The young woman in LATTA III [62] presents a similar picture, but uses her sight to speed up her work as a cotton-winder.

For SEYDEL [58] it was

> discouraging to see how she breathed more freely once the lesson was over, and how she immediately fell back again into her earlier fashion of gaining an impression of objects by feeling and the other senses alone. She herself also confessed on occasion that she found no enjoyment in learning to see, and that she would sooner not see at all.

Seydel was well aware that the difficulty here was solely a matter of volition, and employed a very noteworthy method of stimulating her will:

> It was not till a month or more after the beginning of the visual trials, when the patient had been punished for some days by paying no attention to her, that it could be noted for the first time that she was showing a more active interest and attention towards the tests than before.

By this means he achieved what he wanted of the ten-year-old girl: this inattention had wounded her so deeply that in order to gain notice once more she now wanted to show that she had the ability; and once she had thereby been got to participate emotionally in the learning-process, success was assured.

This is an example of how shrewd a psychological understanding is needed to assess the effects upon the learner. In the two previously

mentioned cases, for example, this technique of inattention would have been a complete failure. It may be asked, however, whether in Vurpas-Eggli's two cases it might not have been possible to get over the purely vegetative instinctive stage by awakening their interest in seeing; by associating it, for example, with a gratification of their play-instinct, while at the same time restricting their opportunities for tactual impressions, for instance by putting thick gloves on them.

MOREAU [63] sets his boy so energetically to work that it is of no avail to him when he says, for example:

> 'It's Sunday to-day, so there's no work' – or – 'But you haven't any time, you've got to put on dressings!'

His indolence discovers all possible excuses for escaping the lesson-period:

> It's no good to-day, and besides, this finger of mine is hurting.

In this case, however, it is not mere laziness only, but obviously also a great liability to fatigue, owing to the superabundance of impressions:

> The first time the sister took him for a walk in the town was an occasion for astonishment, but also for dismay. On mounting a tramcar, he thinks that the houses passing before his eyes are going too quickly. 'I don't like that at all, it's going too fast.' The sister takes him up to a shop-window, but there are too many things in it, and he gets bewildered. Only the colours interest him; he knows perfectly well that the goods set out are separated from him by a sheet of glass. When, in a large department-store, he is shown toys that are quite familiar to him, he cannot describe them. There are too many of them.

This rapid fatigue was naturally much worse in the early stages:

> It often made one despair to see how much more quickly this boy tired than those of his own age. To begin with, everything always went well, but then after a short time there appeared signs of nervous exhaustion; the answers, preceded by deep sighs, were thrown out at random, and one had to stop. For it would have been simply useless, if not actually harmful, to continue. Progress had therefore to be sought in short and frequent sessions, in order to avoid this premature drowsiness. The promise of a delicacy, of a somewhat unexpected kind, namely bacon, had a lively effect on his desire to work. Abundant use was made of this incentive.

Even four months after the operation, Moreau again reports:

> Henri D. tired so quickly as to drive one almost to distraction. The sessions could still only be of very short duration.

Now whatever the motives may be in the individual case, whether

they are primarily intellectual, or rather of a psychological kind, it emerges, in any event, from all the cases, that the doctor or psychologist undertaking the visual tests has to overcome powerful obstructions or resistances in the process, and must be clear as to the reasons for crisis before selecting his pedagogic method. This is all the more important, since his patient is emerging, intellectually and mentally, from a sphere that is quite peculiar and largely shut off from the external world, and in general is suffering not only from congenital ocular defects, but owing to this trouble has also remained of intellectually mediocre attainments and in many cases become mentally and physically stunted. After the first visual trials, as soon as he has realized that things are not going to go his way of their own accord, he is all too liable to fall into the state of mind that 'I just can't do it', and will all too easily be induced to draw for himself the conclusion:

> But things were quite all right when I could not see; why then do you pester me with something that is none of my concern?

He almost always finds himself in a state of distress, in which the main factors are, on the one side, an awareness of intellectual incapacity in relation to the size of the task and a consequent despondency about it, and on the other, a sensory hypersensitivity. But both of these can only be overcome by an energetic and persistent effort of will on the part of the patient himself. And since the burden of both these factors, in conjunction with natural indolence and the tendency to persist in the old accustomed ways, all too easily impels him into that mood of resignation which is so dangerous when it comes to learning to see, the pressure must also be applied, in the main, on the side of the will.

It will therefore generally be a matter of discovering that aspect of the patient's character where his will is relatively best developed, even if it be only in instincts of a quite primitive kind. His will must then be activated as strongly as possible in this direction, and at the same time his situation must be so arranged that he can only realize this will when he makes use of his new sense. An influence in this direction will normally be much more readily attained by reshaping the satisfaction of his daily needs, rather than by systematic instruction, which far more frequently occasions this sense of distress in the patient and drives him to passive resistance.

In this whole matter it will naturally be realized that, unless the intellectual and mental attitudes are exceptionally favourable, as for instance in Wardrop, Franz, Latta I and others, the process of learning to see

almost always represents a long struggle, calling for great patience and endurance. This emerges all too clearly, indeed, from the passages already cited.

In what follows we shall disregard these distracting features encumbering the learning-process, it being indifferent at what point they arise and how long it takes to overcome them; we shall in any case frequently encounter their effects as we now set ourselves to follow out in our material the development of actual ideas of shape in patients of this kind.

3. Differences of Shape Perceived Immediately

Amongst other matters, we also mentioned above the initially uncontrollable ocular movements as a reason for the newly sighted person's early indifference to everything connected with shape. But it was not intended by this that in this initial stage there is no visual givenness of shape at all. At all events, there are in fact a number of examples, even on first exercise of vision, where in spite of the nystagmus the patients, on simultaneous confrontation with two or more figures, *incontestably report differences of shape*, even though they cannot state the shape of any of the figures presented. We have already had such a case from Nunneley (p. 107) and also from DUFOUR (p. 141), where the young man was presented with a square and a circle cut out of paper.

'Do you see a difference between these two pieces of paper?' – 'Yes.'

Elsewhere (before this) Dufour gives a further example:

> I then showed him two pieces of white paper, as stout as thin cardboard. These formed two elongated rectangles, three and six inches long respectively, and of the same breadth. 'What do you see?' – 'White things.' 'Are they alike?' – He answered hesitatingly 'No.'

The spatial concepts of 'longer' and 'shorter' are still lacking however; what he has to do, in fact, is to take the seen difference of length, not yet recognized as such, and transform it by touch into a difference of time, in order to be able to answer the question, which of the two strips of paper is the longer. Faced with a spatial question, the congenitally blind person always produces a temporal idea as a spatial one.

WARDROP II [16], though he did not himself make any experiments with his patient, reports:

> She said she saw different forms in various objects which were shown to her.

When . . . a silver pencil-case and a large key were given her to examine with her hands, she discriminated and knew each distinctly; but when they were placed on the table, side by side, though she distinguished each with her eye, yet she could not tell which was the pencil-case and which was the key.

FRANZ [17] records, on the fifth day after operation:

He was now for the first time able, as he said, to look through the [non-visual] spheres, and to perceive a difference, but merely a difference, in the surrounding objects.

Later we read:

On the conclusion of these experiments I asked him to describe the sensations the objects had produced, whereupon he said that immediately on opening his eye he had discovered a difference in the two objects, the cube and the sphere, placed before him . . .

TRINCHINETTI [18] also remarked that his two child patients (ten and eleven years old) failed to recognize their accustomed tactual objects by eye,

although they very readily distinguished these objects from one another.

ALBERTOTTI [39], with his dark-room method already mentioned, arrived

with great difficulty, to the point of being able to distinguish a round cardboard disc from a square one, a spoon from a fork, without resorting to touch; but here he confined himself to the solitary observation that these objects were not alike.

GRANT'S twenty-year-old young man [4] is described by the anonymous *rapporteur*, on the first occasion that he saw:

The surgeon [Grant] stood before him with his instruments in his hand. The young man observed him from head to foot; after which he surveyed himself as carefully, and seemed to compare him to himself; and observing both their hands, seemed to think they were exactly alike, except the instruments, which he took for parts of his hands.

RAEHLMANN I [46] is shown a sphere and a cube,

both made of similarly-coloured wood and of the same diameter. On seeing the two objects together he recognizes that they are different, but does not know which is round and which is square.

AHLSTRÖM'S little girl [51] remarks spontaneously at the first trials,

that she could clearly see the objects (as different).

In MOREAU'S case [63] the young patient distinguishes very quickly

and pretty accurately between two objects that are similar but of different size. At the sight of two squares of different size and colour he immediately says:

'The big one is red, the little one white.'

This latter experiment relates, however, to a period when he had already acquired the concepts of 'bigger' and 'smaller'.

It appears from these examples that in the normal case the patient is aware that it is not the visual objects that are in motion, but his eyes, owing to nystagmus. In only one case did the patient have the illusion that visual objects were swinging to and fro, and so constantly changing their direction. In the above-quoted cases, on the other hand, visual objects appear as persisting in the same direction as the observer's head. He cannot fixate these things, indeed, because the automatic oscillations of his eyeball are continually shifting the lines of fixation to and fro in various directions independently of his will; but in spite of this he knows that he is dealing throughout with the same fixed object, even though in actual fact it is only projected for a time, by these oscillations, on to different parts of the retina, and also appears in the meantime, at fleeting intervals, on the *fovea centralis* as well; whereas the direction from his head, which is held still, does not alter.

Even the diffusion circles caused by lack of the lens do not alter the outline so persistently that it cannot be recognized, especially with larger objects. In any case, perception of shape was no better in those who had already been fitted with cataract spectacles.

4. Perception of Shape with Assistance from Touch

Thus although the newly sighted can perceive the shapes of visual objects as different, if they actually pay attention to this, they still have no idea, as yet, of the individual shape seen, nor can they at first say anything about it. Initially *the sense of touch* remains *still dominant*; they continually try to replace visual impressions by tactual ones, in order by their aid to recognize the object. If they are then urged, in the course of these tactual manipulations, to look consciously at the object, they soon become aware that their earlier tactual schema can also be traced out visually on the objects; they thereby soon arrive at the point of doing what Latta's patient had already succeeded in immediately after operation, namely to feel out the contours of the visual object in

imagination, creating for themselves a fancied tactual succession for the visual object and arriving by this roundabout method at the correct name.

Something of the sort is present, for example, when WARDROP II [16] tells us:

> In the evening [of the third day after operation] she looked at her brother's face and said she saw his nose. He asked her to touch it, which she did.

FRANZ'S [17] second deliberate experiment with his patient, which had already been preceded, over several weeks, by improvised interim tests, was to give him a sheet of paper with two strong black lines drawn on it, one horizontal and the other vertical.

> When I asked him to point out with his finger the horizontal line, he moved his hand slowly, as if feeling, and pointed to the vertical; but after a short time, observing his error, he corrected himself. The outline in black of a square (six inches in diameter), within which a circle had been drawn, and within the latter a triangle, was, after careful examination, recognized and correctly described by him. When he was asked to point out either of the figures, he never moved his hand directly and decidedly, but always as if feeling, and with the greatest caution; he pointed them out, however, correctly.

During a further experiment his patient explains quite clearly how he proceeds in this determination of shape, namely

> that he had not been able to form . . . the idea of a square and a disc until he perceived a sensation of what he saw in the points of his fingers, as if he really touched the objects.

The first mistaken indication of horizontal and vertical again shows that he had not acquired a spatial idea of these two concepts from touch. But when he then pointed with his finger to the wrong line, he noticed from the course of his muscular sensations that this sequence did not correspond to what he experienced tactually with a horizontal line; so it must therefore have been the other one. By this experiment he had learned to coordinate tactual and visual movements, and now goes on to apply this experience, somewhat uncertainly, to the next experiment. He discovers further, from the second experiment, that in this imaginary traversing of the shape with his finger his gaze must at one point take a sharp turn, and concludes from this that there must be a corner there; he finds more such corners, counts them, and now knows what sort of a figure he has before him. Since he is presented with a circle interpolated between a square and a triangle, he also gets a very definite idea of the

contrast between straight lines, which bend sharply at corners, and the circular line bending in a continuous gentle curve.

What he has thereby acquired, however, is far from being any total shape of 'square' or 'circle'; for the time being he has, indeed, nothing more than a means of deciding visually whether a line is straight or curved. If it is curved, he decides for a 'circle'; if the lines are straight he has to look for and count the corners.

Two and a half years after her operation, MINER'S twenty-two-year-old girl [59] was still so far rooted in the old tactual sphere, since no one had troubled about teaching her to see, that she felt out all her visual impressions in imagination and even accompanied this successive visual feeling-over with tactual movements:

> When Miss W. was directed to count the sides of a hexagon, but to shut her eyes the instant she caught herself making any movement, and then begin again, I found that she was not sure of the number of sides after observing the figure a total of five minutes.

LATTA [60] himself provides another such example: his eye surveys a pattern of holes in the seat of a garden bench, the holes forming two parallel lines, joined at one end by a curve. He simultaneously outlines a low flat arch in the air with his hands, and then compares this design of holes with the arch (for climbing roses) over a garden gate.

5. Successive Scanning of the Outline. Gradual Abbreviation of this Process

From these few passages it will already have been noticed that shape is not simultaneously presented to the observer's gaze, but that he *successively traverses it by eye*. This, however, is not only the case with those patients where one might be inclined to attribute it to the fact that in this traversing by eye they were carrying out an imaginary process of touching, which is, of course, by nature necessarily a successive process. In the other cases also, where there is no question of concurrent imaginary touching, we find, indeed, the very same process, namely that a simultaneous straightforward possession of the total shape is no more a datum for the newly sighted than it is for those of normal vision, and hence that the process of recognizing shape becomes a successive affair which can only later be unified into a total perception. For the operated patient, therefore, the recognition of shape is closely analogous to the traversing of an object by touch with the finger. The examples referred

to on pp. 112, 115, and 118 already point in this direction. Some further instances may be cited at this point.

Of HOME II [14] it is reported (*cf.* p. 118):

> On the 19th the different coloured pieces of card were [again] separately placed before his eye, and so little had he gained in thirteen days that he could not, without counting their corners one by one, tell their shape. This he did with great facility, running his eye quickly along the outline, so that it was evident he was still learning, just as a child learns to read.

Thus in spite of long practice, the characteristic features of a regular quadrilateral, with its pairs of parallel sides, had not yet dawned upon him. And yet it would seem as if here the process of recognition was already beginning to become automatic, so that one day the judgement 'quadrangular' would already be given straightway on seeing, which could then easily lead to the belief that it had always been the case that shape was simultaneously presented.

HEYFELDER'S girl [22] recognizes a cross by touch only, though the has already traversed it not only by eye, but also with a finger.

SCHNABEL II [34]

> reported correctly whether a sheet of paper was round or cornered, and how many corners it had. In doing so she moved her eye slowly along the outline of the piece of paper and let it pause a little at each corner.

Her inability to perceive total shape, and her corresponding need to have the schematic indications (in this case for 'corners') as sharp and distinctive as possible, are plainly evinced in the sequel:

> In identifying round, triangular and four-sided sheets she was only rarely mistaken. But she fell into frequent errors in describing five-to-eight-sided cards, where the polygon had only a small surface-area, and the corners also were therefore only slightly marked. Thus a regular octagonal card, for example, with two-inch sides, was sometimes described as round.

Later we are again told:

> She counted correctly five strips lying side by side, and on being asked which of them was the longest, she first cast her eyes along the individual strips, but without being able to decide.

This counting-out of corners by the wandering eye is frequently recorded, for instance by Francke and UHTHOFF I [45]. The latter was struck by this lack of simultaneous presentation of shape and was thereby led to investigate whether this might not be due to a restricted field of vision; but it proved to be normal.

It is even more frequently evident now that at first he is not capable of correctly recognizing a presented four-sided object as such; when he is then asked to indicate the corners of the object, he often does this quite correctly. Weeks pass, during which the patient is frequently practised in the recognition of round, four-sided, triangular and so forth, before he is capable of distinguishing these different forms by sight alone with any sort of certainty.

It naturally makes no difference whether a figure is presented in full outline or merely indicated by its corners. Points of this sort on the card are not simultaneously grasped either. RAEHLMANN I [46] undertakes an experiment of this type with a view to learning to count. In this case also it was established on investigation that the visual field was normal.

He was shown white cards with black spots painted on them, of three inches in diameter and the same distance apart, and was asked to report the number of round black spots; after numerous vain attempts he first recognizes the card with two spots, characteristically seeking out the individual spots, not by moving his eyes, but by moving his head, shifting it to and fro and then counting the two spots. The same idiosyncrasy was repeated when cards with four, five and six spots were presented. His typical procedure is to hold his head rigid and first to direct it to one, then to another, and so on along the row of individual spots, taking care not to move his eyes in the process. When looking at the card with two spots, which are situated in line together, he first moves his head to left and right at the level of the spots, then, with similar head movements, he scans the surface of the card above and below them, evidently to convince himself that there are no further spots; only then does he give his reply.

In this case also the process gradually became automatic; already, five days later, we read:

He counts the spots correctly, but only after having first sought them out individually by moving his head, as before; but now the information is given more quickly and exactly.

A month later:

He now recognizes the spots on the white cards at first sight, without moving his head, up to the number of six.

This is about the same number that a normally sighted person can take in simultaneously 'at one look'; beyond that he has to count and shift his gaze.

UHTHOFF I [45] makes a similar counting experiment with matches: the boy gives the number wrongly,

> since he sought out the ends of the matches successively by eye, and thus arrived at approximately twice the number actually present.
>
> Even on re-examination two-and-a-half years later, the boy still clearly counts by fixating each individual object in succession, but now makes use of pronounced sideways glances, in contrast to his earlier procedure, where he kept his eyes stationary and only managed to fixate somehow by sideways movements of the body.

When directed to an object by suitable questions, UHTHOFF II [56] begins, likewise,

> by seeking out the object with his eyes, as it were, traverses along it from one end to the other, then recounts its individual features, for the most part correctly, and so arrives eventually at a correct recognition of the object.

SEYDEL'S ten-year-old girl [58] was given two to three hours' instruction daily for three weeks; at the end of which it is stated:

> Till now it could never be established that she had correctly identified by sight objects not previously shown to her, though she was already capable of feeling such objects over from end to end by sight, as it were, which must certainly be regarded as a definite step forward.

Of the experiment recorded by MINER [59] it should be noted that it was not undertaken till two and a half years after the operation. Though the patient was not making full use of her sight, she already possessed imagery, and was likewise quickly able to grasp new images and to retain them in her memory. For all that, the test is of some interest:

> By showing some novel figure to Miss W. for a few hundredths of a second through an exposure shutter, it was possible to study how she perceived, imaged and interpreted it. After repeating the exposure many times, her method of counting the sides of a figure could be observed. With practice she was able to obtain an indistinct image and then count the sides after the picture had been withdrawn, although she could not count the sides during the time of exposure. Kinaesthetic sensations undoubtedly play a most important part in her conceptions of number and space.

Miner actually maintains that there is no such thing as simultaneous possession of a total figure, and that we always first construct it successively. He questions

> whether visual images have spatial meaning apart from movement. In no case, I believe, has Miss W. ever questioned the extension characteristic of her visual sensations.

Of LATTA I [60] it is observed by Dr Ramsay, the surgeon:

> . . . he seems . . . to arrive at a perception of the whole through perception of the individual parts. He cannot take in things at a glance.

6. The Search for Schematic Clues

In the above-cited passages we have already had indications of the direction in which visual learning now develops in regard to shape: as with touch, before the operation, the patient attempts to make the *recognition-process easier* and shorter. When, as a blind person, he took a new object into his hands, he first sought to get an exact impression of its texture, then investigated the object for special recognition-features accessible not only to touch, but also, by tapping, to his ear; finally he also smelt and licked it. In dealing with visual objects he has now long since brought these impressions from the other senses into relation with his visual impressions. But his task, however, consists in identifying the object by visual impressions alone. The other senses already provide him with features by which to recognize the visual object; he only has to encounter one of these features, a sound, a smell or a taste-impression, and he knows what it is in front of him. Hence it is quite understandable that for his sight also he should seek to discern a special distinguishing feature in visual objects, in order to save himself the time-consuming process of completely traversing the visual object by eye on each occasion, and each time combining these successive impressions into a total idea. The appearance of this visual recognition-feature will already be enough to guide him as to what he is confronted with. Just as, with touch, he could identify the whole by means of a fleeting partial impression, so now he also attempts this with the new sense. He often continues to reinforce this sort of visual learning by tactual control, paying visual attention to precisely that which had already been particularly easy for him to identify by touch (e.g. corners). Here, as before, he takes the part for the whole, infers *ex ungue leonem*, and recognizes 'sister' by the nurse's white apron.

This represents a sort of *carry-over of the schematism* in the patient's method *of seeing*, a collecting of characteristic data belonging to an object and their unification into a schema for this object. The schema 'wineglass', which had already had its special features for touch and hearing, and on occasion also for taste and smell, is now enriched by a new, visually experienced feature, such as the typical reflection on the glass. A formal conception of the total shape is thereby precluded from the start; there is a deliberate self-restriction to partial data. This may be merely perseveration in an earlier habit, but may also be consciously

employed as a sort of cheating, in order, as it were, to be rid of the tiresome interrogator during visual instruction.

This 'seeing' by means of schematic features is exemplified in our material by a lengthy and varied series of instances.

Thus WARE I [11] writes:

> Master W. [whose pre-operative powers of vision were already quite considerable] knew and described a letter, not only as white, but also as square, because it had corners; and an oval silver box, not only as shining, but also as round, because it had not corners: he likewise knew, and called by its name, a white stone mug, on the first day he obtained his sight, distinguishing it from a bason, because it had a handle.

He had obtained this schema shortly beforehand on the first day, from a table, whose situation was already previously known to him.

HIRSCHBERG'S patient [24] was led into errors by such schematic identification:

> In front of a large bookcase he said: 'It's a stove, it's just as big as a stove.' Similarly, on the street a quarter-of-an-hour later, he took a fountain for a tree: 'It's big, it's round, it's a tree.'

In this case, however, he is not relying on individual parts, but has already abstracted the major features of shape during the first repeated visual experiences of various objects. A tree is 'big and round'. When he afterwards encounters another object to which this schema 'big and round' applies, he reverses the schema, as it were, and declares 'tree'.

He recognizes his own face in the mirror, because it has a 'shade' (over the eye). In this case the part indicates the whole. Though this in itself could not have led to the right answer if he had not known from the situation that he was the only one in the room to be wearing such an eyeshade. The prior possession of all these individual details of the situation also forms part of the schematism that he had already developed systematically before the operation, to enable him to orientate himself. For, thanks to this knowledge of the situation, the conceptual possibilities are already restricted, in the sense that, in the garden for example, he only needs to have the schema 'garden' present, with everything it contains, and can leave all other schemata, such as 'house' or 'room', out of his present field of consideration.

> He recognizes small, well-tinted photographs as 'pictures', because they are white and square.

This example is again similar to the first.

SCHNABEL II [34] is set to determine which of five strips lying together is the longest.

> She laid the strips parallel (as in touching), so that the lower ends were set in the same line, whereupon she said that they were all equally long, which was in fact the case.

She did this after having previously failed to get the answer by eye alone. Here, therefore, it is more a knowledge of the schema for solving the question proposed to her.

An example from FISCHER [44] is also very characteristic:

> On the second presentation of the cat, the only animal so far shown to her, she again recognizes it as such, but merely because it was the only moving thing that had been shown to her. From now onwards, everything else that moved was also 'the cat', e.g. a hen, even on the twenty-first day; a proof of how weak her grasp of visual images still is, and how far she attempts to arrive circuitously at the concepts of what she can see but cannot construe.

Here, therefore, Fischer is already perfectly correct in his conception of the child's method of interpreting her visual impressions.

In RAEHLMANN I [46] these schematic features are actually employed in learning to see:

> The patient was then shown the oil-painting that he had already seen earlier; at first he confidently asserts that he now has the mirror in front of him. When he is told to move his head, it strikes him at once that the picture makes no corresponding movement, and after he has tried some further experiments, moving his hand and body in various directions, and finds that the picture remains still, he concludes that it cannot be his mirror-image, and must therefore be a painting in front of him.

Thus in spite of frequently seeing his own face in the mirror, he has not yet acquired any image thereof, so that the shape of his head can also be no criterion for recognition. Nor does he yet recognize by visual impression alone the difference between glass and a mirror. Both exhibit, for him, the same characteristic sheen on the front surface. When this phenomenon of reflection is present, it still has an alternative meaning for him, either as a mirror or the glass over a picture, and he can only assure himself as to which of the two it actually is on any occasion by carrying out these trial movements.

In SEYDEL [58] we see how indolence and lack of interest may also be the motive for resting content with a partial impression:

> Persons seem hardly more deserving of her interest. The first time she was brought before the nurse who had been looking after her daily

> for a month, she could make absolutely nothing of the impression of her face. On the fifth day of training she recognized a few people, but based her judgement on completely gross external features, such as a white apron or an eyeshade.

In contrast, she was greatly interested in animals, as could be seen from the fact that even before the operation she had made detailed inquiries as to their appearance. Nor is she content, in their case, with such auxiliary features.

> She stated that she had learned exactly what a rabbit looks like; she knew that it has long ears and may be brown, grey, black or white. For all that, she did not immediately recognize by sight the first rabbit I showed her.

She did, however, learn to know these animals in a very short time, whereas with people no real progress had been attained even a month later.

This tendency to remain content with the schema, so as to save herself the trouble of exact inspection, is also shown by this girl in orientating herself in visual space:

> If, for example, a route which the patient had just traversed without difficulty was surreptitiously blocked with obstructions, one could be certain that she would now set out on the return journey confident that the road was still clear, and would stumble over the obstacles.

In the early stages seeing is a constant labour of thought for the patient, which he gladly evades, although before operation he was in fact accustomed to think continually when getting about.

Another striking thing about this patient is that even later she still endeavours to order visual objects so that they form a regular, easily surveyable schema, as, for instance, when counting matches strewn about in disorder.

> It is still notable that, left to herself, she was always trying to arrange the objects to be counted in adjacent rows.

Congenitally blind patients readily acquire this habit, because their orientation is greatly disturbed by any deviation from the normal order.

LATTA [60] disagrees with the above-mentioned explanation given by the surgeon, Dr Ramsay (p. 176), and remarks:

> My own impression from observing him is, not that he pieces things together by a separate study of their parts, but that he goes on looking

until he finds something which suggests the whole and is then satisfied at having recognized it.

That may well have been so in this case, in view of the exceptionally full development of the tactual schema. For by means of this schema the patient had himself learnt the colours, by making use of flowers, whose colour-schema he knew (as a gardener) and which he was naturally perfectly familiar with by touch.

Of great interest in this connection is the case of MOREAU [63], of whom we already know that initially he could neither recognize movement nor name colours of any kind, and even after operation could at first only report light-intensity, and did not arrive until much later at describing the colours of an object. When he was then given a box to look at, he must have been particularly struck in some way by the difference between inside and outside. For now he calls everything that has such an inside and outside 'a box'. Thus a cap is a box, for example, and so too are a mug, a cup, a saucepan and a cooking-pot. Since, in the other experiments going on at the same time, the patient shows hardly a glimmer of shape-awareness, the difference of inside and outside, e.g. in colour or distribution of shadows, may well have been more the deciding factor in his judgement of 'box'.

Moreau, in any event, is inclined to interpret this as a case of schematic thinking. But since the boy can always point clearly to the inside and outside of these 'boxes', we seem already to be approaching here a certain degree of structural apprehension. Even the pan he first grasped as a 'box' from its structure; but he then recognizes the 'handle', and it immediately follows that the schema: 'box with handle' can only be a pan. The following remarks, made on the same day of testing, are still purely schematic.

The sister 'he describes in his schematic fashion: a black cap and then something white'. Here there is no mention of the ordering of black and white. 'Beard' is naturally identical with 'man'. Anything that 'pricks' is square, so that is also the description given to lemonade when it stings his palate. On seeing a sphere he remarks: 'There are no corners on that, so it's round.' Typical also is the experiment with his wooden horse, after he had already seen a live one: again he gives only the colour:

> 'That is white, black, green, red. . . .' 'But say what it is.' After thinking he says: 'It's a horse.' He indicates the head, and, pointing to the mane, he says 'That's the horse's tail.' And when he sees the tail, 'This here is the reins.' He is then allowed to touch the tail: 'The horse has

got another tail, so that makes two.' Thus he has recognized his horse with the aid of what he knew about it: from colour and from familiar details, such as tail, reins and so on.

Similar confusions are found in the GETAZ case [65], which likewise point to the fact that already some structural element of shape is apprehended, but is then applied purely schematically to all objects of similar structure (e.g. bulging objects):

> Vases, jars and pitchers look so much alike that they are a great problem. . . . Having inspected a fire-extinguisher in the hall of a friend's house, she asked why another was needed in the library. The 'other' was a silver vase. The first time Joan was taken to see the country she wanted to know why all the farmers left their hats on the gateposts. The 'hats' were the R.F.D. mail boxes.

We see, therefore, that the patient's grasp of the structure of visual objects has this much in common with his earlier schematic perception, that with both he pursues the same aim, namely to make it easier for him to grasp the tactual or visual object. Yet we have equally seen from these examples that schema and structure by no means coincide, but can coexist for a certain time in a clearly distinguishable fashion.

7. Conscious Registration of all Visual Impressions

Such confusions then gradually lead the patient to realise that, in seeing, the search for schematic clues, or the perception of structure alone, cannot do much to help him; and that he must therefore really go to the trouble of *studying these same shapes by eye*, often for days on end, beginning always from the front, and mostly with tactual aid, and noting all details, such as colour, size, shape, etc. It then commonly emerges that on the following day he has only retained a fraction of the objects learned, sufficiently to recognize them again. If, in fact, the newly sighted person, for his own part, is half averse to this learning-process, then this phase of learning to see can take on a completely mechanical character, like the learning by heart of words in a foreign language; it is also still further prolonged if for scientific reasons the patient is prevented from invoking the aid of touch or other senses, and associating the old impressions with those to be newly acquired. If, on the other hand, the crisis has already been overcome at this stage, then this phase also may be almost wholly dispensed with.

CHESELDEN [5] observes:

> . . . but upon being told what things were, whose form he before knew

from feeling, he would carefully observe, that he might know them again. But, having too many objects to learn at once, he forgot many of them, and (as he said) at first he learned to know and again forgot a thousand things in a day.

HOME II [14] 'frequently forgot what he had learned'.

MARC-MONNIER [38] writes:

> When he wished to learn to know an object, he touched it with his fingers, and having thus recognized it, looked at it attentively. But this first attempt was by no means always sufficient: on the following day he had forgotten it once more, and had to touch it all over again.

NUNNELEY'S case [21] spends days over the distinction of shape between cube and sphere, without being able to achieve an image of their form.

> He gradually became more correct in his perception, but it was only after several days that he could or would tell by the eyes alone, which was the sphere and which the cube; when asked, he always, before answering, wished to take both into his hands; even when this was allowed, when immediately afterwards the objects were placed before the eyes, he was not certain of the figure.

Learning is thus a very slow and tedious process, the essential difficulty about it being that shape is not given to the eye of the beholder simultaneously, as total shape, while the subsequent all-in-one grasp of a successive act of perception, and the uniting of successive impressions into a total shape, is something quite unfamiliar, which can only gradually be instilled. A further associated difficulty is that, even if his visual field is normal, the patient does not yet understand how to apply his peripheral visual impressions to attain a total shape.

HIRSCHBERG [24] writes:

> On the sixth day it was evident above all that in learning the significance of the retinal image the boy behaved exactly as in learning the words of a foreign language. Just as children, from one day to another, retain a few easier words satisfactorily, others less so, and other perhaps harder ones not at all, so he knew at once how to recognize the table-knife, the spoon after some delay, and the fork not at all.

In DUFOUR [26] we see how much more quickly the registering of visual objects proceeds when the patient himself methodically unifies all his means of assistance, in order to gain the earliest possible acquaintance with the new sphere:

> Noé M. soon learns to recognize all objects comprising the simple furniture of a hospital – tables, chairs, beds, household objects, articles

of personal use, clothes, sticks and umbrellas. He touches everything and looks at objects from every angle, racking his brains a thousand times. The majority of the new features thus acquired he retains; others he forgets again, and is then compelled to renew his tactual investigation of these objects, which are not given to him with sufficient precision by visual sensation alone.

On this question of registration, FIALLA [27] writes, on the strength of his six cases:

> When light, sound, taste, smell and touch exert their momentary stimuli, I have no doubt at all that the first impressions already produce their effect; but the brain, the central organ for all that the organism comprehends, takes them up, and the individual will only then be able to give an account of these impressions, when the effects have been many times repeated, until they are well rooted in the memory and result in that resumé which in common life we call habit or practice.

In SCHNABEL I [33] we have an example of the fact that this practice is greatly improved when the newly developing sense is reinforced by a practised sense, such as touch. Thus he says of his first case:

> He learnt fairly quickly to recognize by eye a series of objects which, immediately before showing them to him, I had given into his hand or applied to his nose or ear, or laid upon his tongue. In the course of this it very frequently happened that he would suddenly give the wrong name to an object that he had already often seen before and recognized, so that I had to show it to him anew.

It may be concluded from this that here also vision was still highly schematic in operation and predominantly an exercise of memory; that it was not yet based on shape-imagery, and sought, rather, to create mnemonic recognition-points, which then, after frequent success, were suddenly forgotten.

The same thing recurs in SCHNABEL II [34]:

> She also learned to recognize a knife, a fork, a plate, a key, a watch, a glass, a book, etc., but frequently, after she had correctly recognized one or other of these objects ten or twenty times, she would again name it wrongly.

SCHMIDT-RIMPLER II [37] also confused his visual vocabulary: on the twelfth day after operation

> he had recognized some of the objects correctly by sight; but this knowledge was still very uncertain, so that soon afterwards he again gave wrong names to the things he saw.

In FISCHER [44] we read:

> She also gradually learned to know the other things, but she never

recognizes those that have not been shown to her and named a number of times before.

UHTHOFF I [45] reports:

As a rule the patient retained objects correctly and also recognized them aright by sight alone, once he had had the opportunity of seeing the object some three to six times, and of orientating himself about it simultaneously through one of his other senses; or when he was told what the seen object represented. But much more frequent instruction often had to be undertaken, before the patient had the object securely rooted in his visual memory, and could again recognize it correctly. Not infrequently too, an object which he had already identified rightly on a number of occasions, was again forgotten, namely when a longer period had elapsed since the last testing, and the patient had not seen the object in the meantime.

Uhthoff then conducts some very interesting trials on this seven-year-old boy patient and a one-and-a-half-year-old normally developed child, in order to establish comparatively how long both children would need in order to register their visual imagery of four unusual objects completely unfamiliar to them, until they could reliably recognize them again; these objects were a percussion hammer ('hammer'), a stethoscope ('tube'), a pocket inkwell ('inkpot') and the antlers of a roebuck ('buck's horn'). The circumstances of the first series of experiments were so arranged that the children were repeatedly shown what to do with each object (tapping, listening, opening, butting), while simplified names were given at the same time. They were also allowed to handle these objects themselves. The experiments extended over five days; a free day intervened between the first and second days. The result of these tests was

that the one-and-a-half-year-old child was just about as quick as the seven-year-old blind-born child in grasping the significance of the objects, and remembering what they were used for. On the other hand, the boy learned the names of the objects considerably quicker, and in fact at the same time as the significance of the objects seen. The one-and-a-half-year-old, however, had considerable difficulties and took longer than the boy in also attaching the correct name to objects that were seen, and whose significance was correctly recognized.

A second experiment was then so arranged

that again four objects were selected, which the two subjects did not yet know and had not previously seen; but this time the parallel tests were so administered, that the objects were only shown to the subjects and named, but their significance was not made clear to the children, nor were they allowed to feel them. The items chosen on this occasion

were a small watch-key, a shell, a glass cube and a shaving-brush. Naturally neither of them knew any of these objects.

The tests lasted seven days, but the older boy only took part on the first, second, third and seventh of these.

From this series of tests it emerged that the seven-year-old boy learned the names of the four new objects by sight alone as quickly as in the first series, where he was allowed at the same time to touch them, and their significance was made clear to him. But it seemed as though the more recently acquired visual memory-images did not take root so firmly as those obtained on the first occasion. After an interval of three days, when he had already twice named the objects correctly, he at first failed to recognize two of them again.

With the one-and-a-half-year-old, the correct naming of things in the second series of tests was rendered quite exceptionally difficult, and the learning-process prolonged, by the fact that he was only permitted to acquaint himself with the object through a single sense, namely sight.

For this child the tests had to be continued for several weeks more.

8. Formation of Memory-Images. Abridgement of the Perceptual Process. No Assistance from 'Tactual Images'

These experiments of Uhthoff already show that by oft-repeated perception of the same visual impression the patient eventually preserves a memory-image of this object. Here it is of no essential importance whether the individual patient consciously seeks to register the visual images in virtue of his own desire for knowledge, even if this be done by way of a schema which he gradually enriches; or whether he is half compelled to learn the visual images by heart, in a more mechanical fashion, without really entering into it himself; whether he is allowed, in doing this, to make use of his other senses, or is prevented from doing so. If only he contemplates visual objects in a more than merely receptive frame of mind, then after a number of repetitions a further inspection produces a feeling of familiarity, which already somewhat accelerates the process of recognition. He knows that he has already traversed this object once or more by eye, and has eventually named it as well. On seeking once more for its correct name he can now disregard a certain amount, he no longer needs to take up so many of its details into his thought again, and quickly finds a feature already known to him, which

sets him on the right track; and on finding the name he is struck by a further series of details which he had attempted to take note of, but which had escaped him. Thus at every fresh look further details are added, while others become fixed by repetition, until eventually a mere glance is sufficient for him to find a name for the object in question already on his tongue, as it were. And when, on the other hand, the object is alluded to, the mention of its name furnishes him with the mental image thereof and no longer merely its schema, as before, which he could then hark back to, without, however, conjoining it with an image.

Some very characteristic examples are again to be found in our material: thus HIRSCHBERG [24] remarks, shortly before the discharge of his pupil:

> On the twenty-first day I went over my house with him. He was not wearing spectacles. In spite of this, a variety of furniture and household goods, presenting considerable differences from those hitherto known to him, for example, a large silver candlestick with an unlit candle, a small bronze candlestick – whereas his own candlestick was a china one – and likewise the variously shaped chairs and tables – for instance, a small round metal table – were recognized with complete confidence and in their correct significance. He had thus already arrived at more general intuitive images of the external objects commonly surrounding him.

Now has this patient already consciously grasped the shape 'candlestick'? He definitely knows the structure; 'candlestick' no longer connotes a specific colour or size; by frequent contemplation of his own candle standing by his bedside he may possibly have abstracted essential features, such as the broad base at the foot and the long, smooth whiteness of the candle above, and perhaps also the characteristic thickening where the candle is inserted. In this process of learning, the gradually developing and increasingly progressive abbreviation and automatization of the act of perception is simultaneously bound up with an increasing shift of the boundaries between sensation and perception. Whereas at first everything given to the eye had to be consciously grasped in perception, the degree to which an object still requires to be so grasped becomes increasingly small; while the proportion given by a known awareness of familiarity when the object is merely sensorily given, without conscious attention, becomes increasingly large. In general, the patient no longer needs to fixate complete sections of an object in order to have the image of the whole consciously in mind.

The long smooth whiteness of the candle above was probably the very

first thing grasped, by sight and touch, as a technically essential characteristic of candlesticks, and noted as a major feature of the schema in question. With the chair also, it takes four legs, a seat and a back to make an object, whatever its appearance, a 'chair'. On seeing something still unknown, he will therefore first ask himself, just as the normally sighted do, what it is used for; once he has recognized its purpose, he has thereby in most cases also found a way of giving it a correct name. When Hirschberg says that he recognized objects 'in their correct significance' this probably implies that he was not indeed always able to give the correct names right away, but could state the purpose. In this he certainly seems to have already possessed a somewhat schematic idea of shape, as Hirschberg himself supposes; at least of the top part of a candlestick, the seat of a chair, or the surface of a table.

The above-cited passage from DUFOUR [23] (p. 183) indicated that his patient was also in the midst of this transition from schema to idea of shape. Such intensive inspection of the object with all the available senses is naturally of crucial assistance in the formation of imagery; by the same token, he is also quicker in retaining those objects to which he had already had a personal attachment before the operation, and which he had therefore grown fond of.

This is also exhibited, for instance, in the example given by FIALLA VI [32]:

> In order to make a new experiment, I presented her with the same jar and asked her what it was, to which she answered, without touching, 'That is the same jar as before.'

This jar had supplied the first visual impression she encountered; she had manipulated it by hand under visual control, and this impression had remained with her, since it had not been erased by others in the meantime.

In AHLSTRÖM [51] also, the acquisition of imagery was relatively rapid, and this again owing to the particular intensity of repeated acts of registration:

> When she had seen and felt an object several times, it was subsequently easy for her to recognize it again by sight alone; in order to do this she did indeed require, in most cases, to have had the opportunity of seeing the object a number of times and touching it simultaneously, in order to learn its nature by feeling; only a few objects did she already recognize at the second examination by means of sight alone; in other cases three or four inspections were necessary, and some she could only grasp with ease after the lapse of a week.

Ahlström took particular note here as to whether it was easier for her to grasp objects already known by touch before the operation than those completely strange to her; but he could not detect any difference. This suggests that these were genuine acts of visual registration on her part. Here too, recognition was first effected by schematic features. But that more than this was already present at this stage can be inferred from the fact that, a short time afterwards, vision was already the dominant factor in her orientation and practical life. She must therefore have already possessed so many images that the objects in her everyday environment seemed familiar, and no longer called for reflection.

In SEYDEL [58] no visual impressions at all were retained for a long time. It was only the rabbit, the playmate of her blindness, whose visual schema (colour, long ears) she already knew before operation – though she failed to recognize it on a first encounter – that she already identified at once on the second occasion. Seydel therefore supposes that this may well have been the only image that she had preserved over the years of her blindness, since the time when she first saw; whereas she no longer had any image of her mother, for example. But this assumption is needless; on the contrary, it is quite possible that, in view of the intimate emotional relation between the child and her pet, the simple experience of seeing and touching was sufficient to leave behind an image at least of the head, with its long ears.

With objects, the acquisition of images took over a month, since she took no sort of interest in this. But here we find the notable phenomenon that, despite her inward passivity, and without her cooperation, the frequent reception of the same visual impressions itself gave rise to a sort of accumulation, with the result that, despite the interval of some days, the girl suddenly identified the objects often shown to her but never recognized. It was these days of inattention which suddenly awoke her interest in learning to see. The avid mental concentration which she subsequently brought to the next trial, had as its result that now the visual images and explanatory words accompanying them, which she had merely submitted to against her will, were none the less available.

That images were actually involved in this, is shown by the following experiment:

> In spite of the interval, she not only recognized all objects previously shown to her, but when asked was now already able – albeit very hesitantly – to pick out the right objects by sight from among a larger number. She proceeded by casting her eye from one to another of the objects displayed, until her line of fixation lit upon the one she sought.

In this searching there must, therefore, already have been at least enough imagery in her mind to enable her to determine of the objects that they did not answer to what was required. Here too, one might well suppose that she could also have achieved this with the aid of a mere schema, without an exact image; and all the more so since with people she had actually adhered, out of indolence, to such schematic marks of recognition. On the other hand, it is also reported of her that eventually, after three weeks, and admittedly under pressure, she began to inspect objects completely by eye, and thus consciously to take in the full shape in succession.

LATTA [60] reports:

> When I saw him on May 4th he had no experience of visual images. He did not understand what I meant when I questioned him about them; but I suggested to him that he should try to recall objects he had seen, and when I saw him again on May 9th he was able to obtain visual images without difficulty.

Some months later, firm associations were also already present:

> Names of places and things with which he was familiar also, in some cases, suggested visual images. Thus the name 'Bradford' immediately gave him a vision of the goldfish. 'Time' and '3 o'clock' suggested no image; but 'clock' gave him the image of an eight-day clock.

MOREAU'S eight-year-old boy [63] had been given a wooden horse as a toy.

> On the 10th October, a horse and cart draws up in the hospital yard. When this is shown to him and he is asked 'What do you see?' he says, 'A cart.' The horse is attended to. 'And now?' 'It's a horse.' 'Does it look like the horse the doctor gave you?' 'Oh, this is a big horse, the other couldn't run.' 'Then have you ever seen a horse before, at home?' 'No, never; they were all cows there.' 'How did you know, then, that this is a horse?' 'How did I know that? I don't know. With my glasses.'

Moreau seems to assume that in this case the boy had already abstracted an image of shape from his toy. But this can certainly be ruled out here, since later (*cf.* above, p. 181) he still describes the mane of this wooden horse as a tail, merely because it feels like one. This makes it very likely that, with the live horse, he had previously heard the arrival of the cart on the road, and now had the prior expectation that he would also see the equipage (= cart + horse) that he had already perceived by ear. How otherwise would he have begun by recognizing the cart as well?

He seems only to have had his first visual image rather later, when learning to read. For this purpose Moreau had had letters three inches high cut out of one-inch wood, so as to be able to make use of both senses to learn by. It turned out, however, that the boy got no help whatever from this, since the letters were equally unfamiliar to his touch. He could not feel the shape of the individual letters, but could only see them. However, since he could not envisage any of the letters as constituents of words, these wooden objects also had no meaning for him:

> About the 29th October he had got so far as to distinguish particular letters, and even to describe them in broad outline, though without as yet being able to name them.

Thus the letters, for him, were shapes like any other, and he had no means of understanding the peculiar significance of these shapes in particular. It was therefore a quite mechanical drill-procedure, which he constantly forgot. And yet the shape of one letter remained with him:

> However, his interest in food was a useful aid to us; when the sister showed him a cake made in the shape of a small stick, he cried 'That's an I.'

This 'I' was thus the only item in the entire alphabet which still remained with him after a year had passed. He never, in fact, got farther than from A to D, together with this I and the L, although the sister-in-charge went to every conceivable trouble to make recollection easier for him by attaching a mnemonic to each letter, such as *bonbon*, *lard* (bacon), and the *dé* (thimble) that his mother was sewing with.

> Two hours later, everything is again forgotten. He is then asked the name of his father: 'D . . .' he says. When he is thereupon shown the D again, and told that this is also his father's letter, he says: 'Oh no! My father doesn't sew, he doesn't need a *dé*.' It can easily be imagined from these answers what foggy ideas must have corresponded to the meaning of the letters in this child's brain. For the rest, he simply could not get to understand that the same letter could serve to designate different things. The letter, for him, belonged to one and only one object. He recognized the letter L very quickly, saying at once 'That's the letter of *lard*.' Bacon was the object of all his desires.

These are all mental processes that every teacher will have observed in learners of the A.B.C.

Upon the whole, he seems hardly ever to have arrived at true images. For even two and a half years after the operation, when Moreau visited

him in his home village, he had still not got beyond describing more than the qualitatively given features of visual objects, and for the rest was guided by his situational awareness.

He no longer possesses the concepts of square and round.

He recognizes not a single one of all the objects brought along, on which he had been instructed for fully a year and a half.

> To create a diversion and stave off his fatigue we began talking for a moment about his recollections of the hospital. He remembered those who had looked after him, especially the sister-in-charge; but this dwelling on the past awoke no image to enlighten him as to the present tests. He still takes the same interest in food; his passion for bacon remains unaltered; but here too his mind registers no association.

He did not even recognize Dr Moreau himself, not even by touch or hearing. And this although his visual acuity was still found to be adequate. All he possessed were imperfect images, of a more or less schematic kind, of a few objects in his everyday environment.

9. Abstraction of Elementary Forms on a Schematic Basis. Awareness of Structure

In many of the passages above cited one might be in doubt as to whether it was primarily a matter of acquiring greater skill, by practice, in the application of the schema to visual objects, or whether, in fact, it was already true conscious memory-images which had led to certainty in the recognition of frequently seen objects.

Such doubt is to this extent justified, that many passages indicate that, so far as the patient has any images of shape, he hardly distinguishes them at first, and at bottom possesses only *a few basic forms* or spatial relations, which are *still strongly schematic in character.*

Thus, WARDROP'S woman patient [16] remarked that she saw different forms in various objects shown to her, and on asking her what she meant by different forms

> such as long, round, and square, and desiring her to draw with her finger these forms on her other hand, and then presenting to her eye the respective forms, she pointed to them exactly.

These few basic forms apparently served her to make a first rough classification of visual objects, before then drawing upon the aid of colour and a few learnt features. That she had not acquired any pro-

nounced idea of shape in these objects, can be seen from the remark that:

> She had as yet acquired, by the use of her sight, but very little knowledge of any forms;

and this because of her difficulties of fixation.

HEYFELDER [22] actually gave his seventeen-year-old girl patient systematic instruction in such basic spatial concepts:

> Thus, by the use of coloured paper pasted into a book, I introduced her to the concepts of straight and wavy lines, of a circle, a square, a triangle, striped, checked, spotted and so forth.

In HIRSCHBERG [24] we are told:

> To-day, in order to describe something round, he drew with his right forefinger in the palm of his left hand a more or less elliptical continuous line; and to describe a square he drew with his right finger a more or less square linear outline around the top joint of his left forefinger.

For this patient also, therefore, the most important thing about a visual object is first of all to determine whether it is round or cornered. But these are none the less shapes which he already consciously possesses in his imagination.

In spite of close inspection, DUFOUR'S twenty-year-old patient [26] failed to recognize a pair of paper-scissors which he knew by touch, and subsequently investigated and registered the impression in every detail under visual control.

> Three days later, I showed him three quite small pairs of scissors from my case; he recognized them at once without touching them, and although there was only a basic analogy of form between these and the large pair of scissors first shown to him.

The peculiarity of form in this case was constituted for him by the long straight-edge with two rings at one end; and his attention had actually been drawn to this. This single basic form therefore remained with him for some time, firmly fixed in his imagination. This too is something frequently to be observed, that for some time only a single visual impression takes root, and preoccupies the patient's imagination so intensively that at first there is no room beside it for any other idea.

In MOREAU [63] distinctions of form are also highly schematic, and even the few basic forms seem to have no real character of shape, but merely provide a schematic clue:

> We succeeded nevertheless in imparting to him a crude division of forms: square, circle, sphere and circular disc. He gave concrete

embodiment to the concept of a cube by the image of the box; similarly, every cornered object is square, and every object without corners is round.

This receptacle or box (*cf.* p. 181) seems to have been the only object to which he attached any imagery of which the image at least had some sort of form.

In AUGSTEIN [64], conscious vision proper did not begin until the fourth week, but rapid progress then ensued, which even extended to the grasp of shape.

It was now notable that once an object had been correctly identified by the aid of touch, it was not only easy to recognize it again, but it was always correctly identified in a great variety of sizes and shapes; so that after he had got to know scissors and knife, for example, he at once recognized the largest and smallest scissors and knives correctly.

Whether he was in fact so certain in his judgement of form that he also recognized it on any scale, provided that the interrelation of the parts corresponded to the form of his image, cannot be definitely stated; for even if he did recognize objects in many different shapes, he was possibly not so much guided by the shape, but was seeking to elicit the purpose.

10. Independent Interpretation of New Visual Impressions, on the Basis of Images already Acquired

The examples hitherto may possibly be attributed, more or less, to skill acquired by practice in the recognition of individual schematic features, without a truly spatial idea of shape being as yet definitely involved; but one must certainly postulate such ideas at the point where the patients *make use of these images* in order themselves to identify newly occurring visual impressions by eye alone, through comparison with similar memory-images, and so themselves to *enrich their stock of visual imagery*. There is the more reason for regarding this as a proof, since this stage can only occur when the patient has in the meantime acquired a real interest in the data of his new sense. Since, in fact, all his other mental powers are thereby enlarged as he learns to see, the way is now also clear for the development of images having form, like those of the normally sighted. Having reached this point, the patient also begins to venture judgements of his own about new visual impressions; here the supposed correspondence with other images may naturally be

erroneous; for since the new visual data thus sensorily given have not yet been furnished, by prior inspection and explanation, with a definite content of meaning, they are likewise interpreted without prejudice, according to the sense-impression given to the eye. In the resulting misjudgements colour naturally plays a certain role also, as well as shape.

MESMER'S case [9]

> described the Danube flowing past as a long and broad white streak and also indicated the exact beginning and end of this streak.

One of BEER'S fourteen patients [10] sees the same Danube

> as a huge mirror, which he was eager to approach, since he took the motion of the water merely for a glitter on the shining surface.

In this fourteen-year-old boy a number of such misjudgements caused a reaction to set in:

> He became so cautious that he no longer named any object straight away, but merely described it each time according to the form striking upon his eye; thus, among other things, he defined a book which I had shown him for the first time as a thing having four sides and four corners; a definition which does indeed fit many books tolerably well.

HEYFELDER [22] was also guided in this direction on pedagogic grounds:

> After she had been brought, often with much difficulty on her part, and after many questions on mine, to apprehend a form correctly by sight, I then subsequently let her test by feeling whether she had seen rightly.

This procedure is likewise intended to assist the patient by means of visual images. Though here it would indeed be useful to know the exact questions and answers involved in such a process of recognition.

HIRSCHBERG [24] reports:

> On the eighteenth day, with the right eye still closed, I tested the left in my room: he immediately recognized the difference between this room and his own, and here too, slowly but surely, he could already find his way about. Of a pear held before him he said at once: 'It's yellow and round', but only recognized the object on touching it; of a dark-brown plum: 'It's black and round, it may be a cork'; but again recognized it at once on touching. Of an apple he said correctly: 'It is yellow and red and round', and then hesitatingly added: 'It's a pear.' After touching he said: 'It's an apple, what I meant to say was, it's an apple.' His progress is unmistakable; he now already has a sufficiently reliable stock of intuitions, so that when faced

with a new retinal image unknown to him he ventures an opinion as to the nature of the object responsible.

In this case there are still clear indications of the close connection between schematic knowledge on the one hand, a still rather limited possession of as yet indefinite and vague intuitive images on the other, and thirdly, situational awareness. With the first object, the pear, he still knows nothing of what is coming; he merely defines the colour-impression; but many objects are 'yellow and round', and this label is not yet precise enough to enable him to pronounce a definite judgement. With the second object, the plum, his thought is still not directed towards a specific supposition, as it were towards 'fruit'; when he says 'black', this means 'dark' for him; for 'black and round' would not be appropriate to a cork either; but the visual impression has a certain resemblance to an old red-wine cork, and the schema 'dark and round', in conjunction with the seen colour, which he is not yet able to describe as 'dark brown', would therefore fit a 'cork'; and he goes on to express this opinion. But since it is again a fruit, his thought is already directed, with the third object, to 'fruit' (perhaps he had even seen a hand plunged into the fruit-dish); but 'yellow, red and round' again applies to many fruits; he is in fact aware of a certain difference in shape from the first fruit observed; but since he is again conscious of the pear as a possible case which this schema might fit, he comes out with 'pear', without yet pursuing the doubt further. He then regrets not having done so, and expresses this in the words: '. . . what I meant to say . . .'

DUFOUR [26] writes:

> In certain cases, when confronted with an object that he cannot touch, he ventures an opinion, and bases himself in so doing on the visual knowledge already acquired.

In this case also, we can follow out his procedure pretty exactly: this young man of twenty first determines the schema of the object, attempts to imitate the shape seen with his own limbs, and by means of the felt postural sensations in them thereupon has an approximate clue as to the purpose; he then knows in what direction to look for a definition of the visual impressions; thus he relies, in effect, on his earlier tactual experiences. This procedure is therefore very similar to that of the examples referred to on pp. 178 ff.; save only that in this instance a more conscious grasp of shape is already present, in so far as he does not feel out the shape successively in his imagination, but grasps the total shape-structure as a whole, and also seeks to reproduce it as a whole.

On looking attentively at a hammer, he suggested, on seeing the shaft:

'It's like a stick'; then: 'It's a stick, with this on top of it', indicating his closed fist. He thought over for a moment what sort of object this could be, but without success, and discovered the hammer on touching it.

A pair of tongs

he likewise examined without touching them, and when he saw them open and shut he suggested: 'It's like a pair of scissors – it's made of iron', but did not arrive at the exact description until the moment he grasped the tongs.

Finally he was brought an auger, consisting of an iron drilling-shaft and a transverse wooden handle. After visual inspection, Noé M. says: 'It's like this and that', indicating with his fingers the relative positions of metal and wood, and added: 'It might perhaps be a corkscrew.' Here, therefore, our patient had found out the object quite accurately, without the use of anything other than sight. He ventured his opinion, basing himself on the general form of the instrument, consisting of rigid arms standing at right angles to one another.

Dufour himself says of these experiments:

Each sensation requires a special effort of thought, which results from comparing the effect of the object on the retina and the effect of the same object on the sense of touch. But in certain cases, the experiences already undergone by the patient are used by him in order to discover the correct interpretation of the visual sensations still unknown to him. This is sufficiently credibly exhibited in the comparison of the shaft of the hammer with a stick, of the tongs with a pair of scissors, and in the exact description of the image presented by the auger.

In FISCHER [44] we find a similar conjunction of schema and spatial image:

A large black cat, shown to her in semi-darkness, she recognizes 'by the eyes'. She is shown a domestic broom without a handle, with the bristles uppermost, and asked whether that is also a cat: 'No, for it hasn't any head.' 'Then is it a rabbit?' 'No, there are no ears on this!' But she does not know what it is. Not until the broom-handle itself is inserted does she say: 'That's for sweeping.'

At the conclusion of a number of such tests Fischer remarks:

The child manifests the need to attach the new impression to the older ones already acquired, and to lay it up in the archives of the cerebral cortex.

UHTHOFF I [45] likewise reports a similar impression:

The confusions perpetrated by the patient in the recognition of objects,

notably in the early stages of his visual studies, are naturally very numerous and in some cases strange; it may be observed in this connection that, in interpreting a new object not so far seen, he draws upon experiences he has had already, and particularly those acquired shortly before. Thus he describes a lamp with a white shade as a 'bowl', a bottle as 'glass', an egg as a 'rubber ball', a rabbit sitting on its haunches with flattened ears as a 'box', and on touching it as a 'cat'; he already knew the latter, and had just previously become acquainted with a larger chest. Such examples show, what is only too natural, that the patient is attempting to utilize the experience he has already gained in the visual sphere for the recognition of new objects.

FRANCKE'S patient [50] was naturally able to make speedier progress in this respect also, because of his pre-operative visual experiences. Francke reports

that in later sittings he can identify individual objects, presented to him for the first time, by sight alone, or else expresses correct opinions about them.

The recognition of things that the patient has not so far seen proceeds, in each case, by combination and comparison with what has already been learnt, a task to which the mental development of children is not yet adequate. To take, for example, the hat which the patient recognized on first inspection, he knew here that he had not yet seen an object of this sort, recognized that it was high and round, could also see that there was a hollow at one end, while the other was rounded off, yet solid-looking, and therefore advanced the opinion that it was a hat.

In AHLSTRÖM [51] we find a striking description of such methods of interpretation. He had put into the girl's hands objects which were also quite unknown to her by touch:

She held them still in her hand, and looked at them closely, naturally without grasping what they were supposed to be, for I had not previously told her this. To be sure, she was often at fault in confusing objects, especially at the beginning, and here it was noticeable how, in attempting to get to know new objects, it gradually became ever easier for her to employ the newly-won sense; for when she named an object for the first time – this was often only after she had thought about it for quite a while – she guided herself by the visual impression which a similar object had previously made upon her. At first she named the object slowly and hesitantly, as though searching her memory for the name, but in later tests she could quickly assign these names.

Here, indeed, sight already dominates almost without competition from touch; she thinks almost exclusively in visual images.

From SEYDEL [58] we learn:

She now recognized for the first time [about five weeks after opera-

tion] two objects which had not previously been taught to her, but which she had chanced to see on the station. From this we were led to conclude that she was already undertaking her own visual studies, and the difference in her attitude also confirmed this opinion: during the pauses she took a look at some particularly striking object not yet known to her, inspected it with interest from every angle, and eventually checked her visual impressions by handling it. This manifest progress appeared to have broken the spell. The number of objects independently recognized by sight increased from day to day.

MINER [59] is particularly struck, in his twenty-two-year-old girl, by

the marvellous ability she constantly manifested to interpret novel experiences which she knew nothing about previously or knew only by description. The compass, for example, was recognized by sight at once from what she had learned about the magnetic needle, although she had never seen one.

In MOREAU [63] it is said (four months after operation):

Thus, little by little, he no longer, or far less frequently, attempts to take refuge in his sense of touch. He no longer tends to let 'the veil of fortune' again fall over his eyes. He begins to use his eyes with success in his dealings with the external world. Thus it is easy to confirm that his walks in the hospital grounds are hours of instruction for him. A tree, an animal, a flower, are all so many occasions for often astonishing and original reflections, and now the joy of living appears a little in his eyes.

In an earlier passage it is already remarked:

On subsequent occasions he is able, when helped out by touch, to recognize the objects customarily presented to him, and these latter become points of comparison, standard objects, to which he relates his later acquisitions. And now it becomes possible for him to form associations among images, constituted out of the imagery first acquired and the intuitive images newly presented to him. Instead of hunting over objects by eye, as he did earlier, he now names them approximately and then proceeds to improve upon his first mistaken description, as soon as the objects are placed conveniently for him at a sufficiently short distance.

This last passage would seem to provide strong evidence that he actually possessed memory-images, although his later behaviour leads one to suppose, rather, that Moreau's judgement was somewhat too optimistic in this respect. His visual memory must actually have been very defective; and it must then have been his complete mental isolation in his mountain village which was responsible for the subsequent loss of

all his concepts. From the following passage it may certainly be inferred that, at times at least, he did employ his sight quite confidently:

> It was an amusing comedy to see how this child, who had previously had to be led by hand, now takes on the role of Antigone. He guides the hesitating footsteps of old people with cataracts straight down the corridors and through the rooms of the wing, leads them by hand into the surgery, or even does them the service of showing them to the quietest corners.

Further amusement is to be had from the description in the GETAZ case [65], of her method of dealing, on her first independent visual excursion, with a broad band of sunlight slanting from a window on to the floor, which she took to be a plank, because she assumed from her tactual concepts that everything perceptible consisted of solid bodies.

> Approaching carefully in order not to bark her shins, she reached down to feel the thing but her hand passed through it. Puzzled, she walked around and tried to feel it from the other side. Her new eyes said that there was something there but her reliable 18-year-old hand told her that there was nothing. She finally discovered that it was a sunbeam.

That a newly sighted person can perceive a visual shape in a fashion utterly different from that of our normalized perception, is shown by the case of HEYFELDER [22], whose seventeen-year-old girl conceived a cross in what was by no means the wholly characteristic and almost compulsive-seeming shape that it has for us; on the contrary,

> she dissected the cross into a long perpendicular, with a spike sticking out to right and left.

And MINER [59] gives an example of how tactual images can influence visual perception, which was indeed to some extent the case already in the above-cited example from the Getaz case.

> The morning after she looked through the university telescope at the stars, she anxiously inquired: 'Could you see any points on the stars?' Her previous touch experience had associated 'star' with a pointed figure.

Inasmuch as our patients now have a certain stock of shape-imagery, and are themselves capable of enlarging this stock, by investigating new visual objects and utilizing the images they have already acquired, the task of the doctor or psychologist in guiding their visual learning is at an end; he can leave the rest to the patient himself, so long as the latter does not immediately relapse into all-too-unfavourable circumstances, as happened in the case of Moreau.

IV

SPECIAL INFLUENCES ON THE LEARNING-PROCESS

1. From Memory

In describing the development of shape-concepts among our patients there is, however, one important factor which has hardly been brought out, namely *memory*. This is intelligible, if only because each *rapporteur* was primarily concerned with his own case, and therefore inclined to generalize his findings. But when in fact one looks at all the cases, with a view to the time needed before the first memory-images were retained in the mind, some quite considerable differences emerge. Since the interest exhibited in the examples cited on pp. 128 ff. was already present almost throughout, though in some cases, indeed, it had been very long delayed, the great differences in time-interval, namely from two or three repetitions up to several weeks of almost daily confrontation, point only to the conclusion that there must have been great differences in visual memory.

But there are hardly any accounts of this. FRANZ [17] alone reports:

> Though he possessed an excellent memory, this faculty was at first quite deficient as regarded visible objects: . . . even when he had seen an object repeatedly he could form no idea of its visible qualities without having the real object before him.

Apart from this, only FIALLA [32] has pursued this question as to the extent of the part played by memory in the formation of visual images; he comes to the conclusion:

> I believe that individual intelligence also has a great influence, and the patients I had to deal with were mentally retarded. Thus I was able to observe that they did not immediately recognize again an object they had learnt to know on the previous day; on the contrary, they had to contemplate it again for a long time, or touch it again, before they remembered that they had already seen the object presented.

In comparison with the other cases, he certainly cannot complain

of bad memory here. What is here referred to as intelligence includes not only mental agility, but also, no doubt, a ready apprehension of all sensory stimuli, both of which must naturally have a great effect in accelerating the attainment of perception proper. Neither of these qualities is of very much help, however, so long as the patient displays no emotional interest in his visual experiences.

Fialla gives a concrete example, from his second case, and shows that her memory for tactually known objects was very much better than for those to which no concept was yet attached:

> On the next [second] day I repeated the experiment, showing her the same objects; after inspecting them for a moment she recognized them again and gave their names without hesitation; to me, this is one more proof of the fact that in the sphere of vision memory plays a very great part. I was especially convinced of this when I showed her an object that she had not previously touched, for example a watch; she then examined it carefully, felt it, and told me that she did not know what it was, whereupon I informed her that it was a watch; she repeated the word 'watch'. Even eight days later, she had to think for a long time before she could remember what this object was called.

In contrast to this, Ahlström, as we know (*cf.* p. 188 f.), made similar experiments, but was unable to detect any difference.

2. From Fantasy

Memory is therefore important for the first acquisition of images in general; but there is also a further gift of exceptional importance to the patient in utilizing these images for the interpretation of new visual impressions, though this quality also is far too little apparent in our material; namely, *fantasy*, which gives further shape to the imagery collected by visual memory. For this connecting up of old images to new intuitions is properly an act of fantasy. The patient has first himself to fill the new visual impression with a content intelligible to him, and must therefore make creative exercise of his imagination. A good example of this is the case of LATTA [60]. Here, his imagination was already at work during his first act of vision, when he felt out the seen brick and ball in thought, with nervous motions of the hands, and thereby indirectly derived the visual shapes of square and round. And when, five months after operation,

> he could easily picture the starry sky, with the planet, which had especially attracted him, in its right place,

and could likewise picture a tank of goldfish that he had looked at for

twenty minutes in Bradford, he owes this, not only to his visual memory, but also in great measure to his imagination, which was so powerfully excited by such things that he had to keep on thinking about them.

The following passage, indeed, almost suggests eidetic features:

> When he had forgotten the particular place of an object in a room he could now sometimes discover it by visualizing and thus seeing in his mind's eye the object in its place.

But the continuation of this passage is extremely characteristic of the fundamental contrast between touch and sight:

> During his blindness his only means of discovering the place of the object in such circumstances was to return to the room and grope for it.

This shows that the blind man can have no exact idea of the mutual positional relations of objects in a room, and also that he does not in any sense remember individual objects as shapes, but only as tactual sequences. If he had any spatial imagery, it would be given to him simultaneously in imagination, and also in its correct relationship to the surrounding objects. But since he is thus invariably compelled to retain all the items of a tactual sequence in memory, individual items drop out of this temporal structure much more readily, and he then has to restore them by contact with the object. Hence, except in musical tonality, the blind man's imagination finds little scope for exercise, and is bound to be very greatly stimulated by the process of learning to see – as is shown by this very case.

> Once he properly understood what vision meant, he made very rapid progress, and his extraordinarily retentive memory enabled him to take full advantage of everything he was told.

This very last phrase 'full advantage' shows that it was more than mere memory, and that his real gift was that of combining all his earlier impressions together and conjoining them with one another, and with new visual impressions, into new ideas. And that is properly the creative activity of fantasy.

Latta, in fact, also says of him:

> . . . his thinking in the blind state was mainly word-thinking, while now it is to a great extent picture-thinking.

3. From Monocular Vision

Before ending this account of the development of shape-perception, it still remains to inquire whether, and in what respect, the *one-eyed*

differ in their development from the remainder. If we disregard those cases in which the second operation followed hard upon the first, since here visual learning proceeded, in effect, by the use of both eyes, the twelve cases certainly belonging to this group are those of Cheselden, Ware I, Home II, Wardrop I and II, Franz, Marc-Monnier, Dufour, Schmidt-Rimpler, Dor, Dunan and Seydel. Of these, Ware I, Home II and Dor had a great advantage, due to their pre-operatively acquired visual experiences, and Dufour, Franz, Dor and Wardrop II, by virtue of their intelligence and experience of life; whereas Wardrop I and Marc-Monnier never in fact achieved proper use of their vision. Only in Dor's case was visual learning particularly rapid, though the report gives no evidence of the details of the process.

Since, in each individual case, there are innumerable factors influencing the course of development, the effects of monocular vision can scarcely be isolated. The only thing that does seem to be common to all the cases is that they showed a particularly intensive and lengthy adherence to the purely qualitative, and took an unusually long time before they could detach themselves from their tactual habits and their self-constructed visual schemata. This seems, at all events, to emerge quite clearly from the more detailed reports of Wardrop, Franz, Dufour and Seydel. All these cases took a long time to arrive at a true idea of shape; though some of them were able to manage very adroitly with their schema.

V

GRASP OF PICTORIAL CONTENT

1. In Binocular Vision

We may now go on to ask how the patient behaves towards the artificial reality of visual objects displayed in pictures. Our account of the development of shape-perception already suggests this much, that even if we begin by disregarding any arrangement in depth exhibited in such pictures, the grasp of their content will invariably become possible only at a later stage of visual learning. For in the first place, the patient will not be able to understand this imitative copying of visual objects if he has not previously grasped an order in real visual space, and has learnt to recognize at least a selection of visual objects by shape. And since, moreover, even for the normally sighted person, the reality of the picture constitutes, not a copying of natural reality, but an absolutely self-subsistent artistic reality – the mirroring of a spatial order of visual objects achieved by means of the painter's craft – the patient himself will be all the more inclined to regard such a pictorial representation, not as a subjective illusion of his own, but as a deception; even when he is already beyond the stage where he merely reports colours.

Hence, in the apprehension of pictorial content, we shall also find renewed evidence of many of the stages of visual learning depicted above; and shall be able to estimate approximately at what point in the development of shape-vision an understanding of the pictorial reproduction of visual objects normally becomes possible. Since, with few exceptions, the patients under review were confronted with photographs or portraits, where the artist is less concerned with effects of depth, it is not difficult for us here to deal separately with the apprehension of shape in pictures.

Before his first pictorial experiment, HIRSCHBERG [24] makes trial with a mirror; the boy's capacity (after 2–3 weeks) is such that, apart from the colour, he reports only the shape-schema (round, cornered) and thus has no true conception of shape.

On contemplating his image in the mirror, he notices a red stripe (his lips) and the movements the doctor makes him perform; he is also struck by something white (the bandage on his eye) and this then leads him to the correct solution, when he is told that he is looking at a face. He thus had no image, as yet, of the human face, since except during the test-sessions he was still obliged to go about with the bandage on. Hence even this first impression of his own face was not yet sufficient to endow him with the image of 'face'.

Thus when the picture of a man is shown to him, all that strikes him at first is again that it is a framed white surface, with something black in it. Since this corresponds to what he knows of the visual appearance of a picture, he reports 'picture'; but he can make nothing of the likeness itself. With small photographs it was exactly the same:

> He recognizes them as pictures, because they are white and square.

But since the picture is supposed to have a content, he looks in it for something he knows, and discovers something round in the tiny ear of a girl, which he at once describes as 'hole', in accordance with the existing resources of his visual imagery. He has no suspicion, as yet, of the possibility of depicting a large object by a much smaller likeness, and therefore seeks his clues, not according to the scale of the picture, but in the natural size to which he is accustomed.

> Only gradually could he be taught that this was a person depicted here, and shown, by tactual experiment on his own limbs, how a half-lifted bent arm could be projected as an angular figure, and so on; at this point he concluded, obviously more by judgement than by direct intuition, that the two lowest portions of the picture were the feet.

This experiment took place on the same day as the trial with the three fruits (*cf.* p. 195). Here we again see how he orientates himself about things as he did with touch, by setting up a visual schema of them ('picture') or being very skilfully guided in his judgement by schematic details ('shade'). But whereas, on this day, he already had a certain idea of shape in Nature, the memory of which he was by this time attempting to utilize, he sees no shape in the reduced scale of the picture, and attempts to combine according to the visual schema.

As early as the seventh day of testing, FISCHER [44] gives his eight-year-old girl patient a small photograph (half-length, passport size): she too begins by noticing only the wooden frame, calls it a box-lid, and reports that there is something painted on it, but nothing more. She too had just previously seen her face in a mirror, but is now in-

capable of discovering nose, eyes, etc., in the picture, even after she has been told that it represents a human face.

On the following day she is given a coloured picture-book, but in spite of detailed explanation is again incapable of recognizing any of the animals depicted therein as shapes (The cat, already known to her, is not mentioned among the animals shown.) A playmate gives her some days of instruction, with the result that, on the eleventh day, she can start by pointing out the four legs of the animals in the picture-book.

This girl also still has no idea of the human face; and she likewise looks for resemblances on the scale of reality; she too is initially content with the schema for the recognition of animals ('four legs'), although during these days she had given much attention to cats and dogs. She then applies the schema to the pictures. But she seems, as yet, to have no clear visual recollections of the animals themselves; for in the picture-book she still learns the animals only by their colour and not by their shape, apart from curiosities of figure, such as long ears.

> While she points correctly to the yellow chick, she completely misses another one painted a greyish yellow.

Colours obviously make a much greater impression, and are more easily retained without conscious learning than is the case with shapes, which first have to be systematically imprinted, together with the significance attaching to them. When, on the twenty-second day, ten days after the apparent understanding of the first picture-book, the child is given a second one, she is at first completely thrown out in her colour-identifications, and now attempts to utilize her schematic knowledge of shape, but thereupon confuses the donkey with the rabbit. She then learns the new picture-book by its novel visual features, relying more than with the first upon individual peculiarities of shape, though even now without any grasp of shape as a whole: an animal with a long tail is a mouse, the one with long stilted legs and beak is a stork, and a creature with eggs nearby is a 'hen', even though it is a snake.

Thus when Fischer hoped that by understanding of pictures he could bring her closer to reality, he did not meet with success; she still had to gain her experience in the real world, by herself, as we have already seen from the passages previously excerpted from this case.

UHTHOFF I [45] devotes a special section to 'the recognition of pictorial and figurative representations of men, animals and objects'. Here too, a number of stages of development can be distinguished. The period of his first, completely unsuccessful, experiments with pictures, in which

the boy merely reported the colours, is not recorded by Uhthoff. The experiments were then resumed again, two months after the operation. With a half-size water-colour portrait, he first notices the glass and something coloured in it, and thereupon announces 'mirror'.

> To the question what he then saw in the mirror, he answered, after a time, 'a cat'.

At a later repetition of the experiment, he says nothing at all, and on the third occasion reports 'picture';

> But he obviously cannot orientate himself correctly as to the figure and its individual parts, and is incapable of pointing them out.

In the case of the 'cat', he was probably relying on a resemblance of colour; for since he was directly acquainted with the cat, we need not suppose that he alluded to it merely in order to say something. It may, for example, have been the colour of the costume worn by the child in the picture (a dark velveteen) which inspired this idea; besides, the size of the figure in the picture also corresponded, more or less, to that of a seated cat. But here too, at all events, shape was again completely lacking.

Only at the fourth test, after he had meanwhile gained an understanding of his mirror-image, did the boy report some details, though these were strongly influenced by the experiments with the mirror.* Even now he apparently sees no shape, but once his assertion 'a boy' has met with approval, he gathers the individual parts together at random, guiding himself by feeling and conducting his examination on the tactual scale of a natural face.

In his postscript on this case, appended to the account of his second patient, Uhthoff remarks:

> It is obviously quite especially difficult for such patients to grasp how so large an object of the external world can find room within so small a space as that of a picture.

It is different, of course, when the pictures selected for such experiments are of known objects and in their natural size:

> Some really good realistic pictures of objects known to him, and in their normal proportions, such as the picture of a matchbox, for example, were correctly recognized.

Uhthoff then gives a further example of this inability to picture, or

* These trials with the mirror are described in detail by Uhthoff, and are best consulted in his own account.

even to grasp the possibility of picturing, a reduction or enlargement of real objects represented in pictorial or figurative form; he gives the boy a small bronze cat to hold, and tells him to look at it; the little bronze is heavy, and the quality of the tactual impression reminds him of a bronze candlestick that he had previously touched; the result is that this object is a bronze candlestick for him, and he is not in any way put out by the total difference of its form. This constitutes a further indication that, in touching, the qualitative and textural completely predominates, for the purpose of the judgement required, over the spatial shape.

Of his second case [56], Uhthoff gives no detailed account, since his observations on this point coincided with those of the first case, especially as to reductions in size.

Thus we have seen from this that it is not just a matter of possessing an image of shape; for in order to grasp pictorial content on a reduced scale, the patient must also have consciously seen a shape recurring in greatly reduced visual sizes, owing to the effects of distance.

That this possession of an image of shape on the natural scale is sufficient for recognition of a pictorial shape, can be seen from RAEHLMANN I [46]. Here, immediately before the first pictorial experiment, the nineteen-year-old patient was shown a dog, which he already recognized correctly as such, and which he then went on to examine closely, and felt over in detail throughout: mouth, nose, ears, hair and legs. Immediately thereafter, while he was still under the impression of this last visuo-tactual experience, whereby he had himself created, as it were, a very thorough image, he was shown the picture of a more or less equally large dog, cut out and depicted on cardboard, at a distance of about one foot:

> After a brief closer examination, he declared that the thing in front of him was likewise a dog.

The image of the dog is now an assured possession; on the following day he again sees a dog, at a distance of ten feet, recognizes it as such, and is able to follow it by eye up to more than eighteen feet away. Unfortunately Raehlmann did not then make any experiment with the picture of a dog on a much reduced scale. Instead, he showed him, some days later, when he already had good vision of material objects, the life-size oil-painting of an elderly gentleman:

> He said that it was a man; but that this one had something peculiar about him, which distinguished him from those he had so far seen.

When he is then shown the same portrait again a week later,

> he said that it was a man, but not a living man, though he looked just like a live one. After looking longer at the picture, he said there was some mobility in it. He was told that it was the painted likeness of a gentleman; he could form no idea at all of this.

This case is again quite specially characteristic, in that the patient has no suspicion that he is confronted with a picture, and is therefore completely unprejudiced in reporting his actual pictorial impressions, which cover the essentials throughout.

Two weeks later again (seven weeks after operation), he is shown for the first time a portrait steel-engraving, one quarter natural size, having just previously made experiments with his own image in the mirror, so that in this case he can already count upon seeing a face:

> The patient now again supposes that he has a mirror before him, and takes the picture for his own face. Having looked at it longer, however, he begins to have doubts; he remarks that the picture is smaller than that seen in the mirror, that it also differs in certain respects from his own face, and finally that the surround of the picture is differently made; he eventually concludes that it must be a painting of a man.

At this stage vision was already completely dominant in him, he was already casting his eye around the central focus of vision, and was also noting the immediate surroundings of a fixated object. By this time he had likewise had sufficient experience with greatly reduced visual images. Since, in this experiment, he was in any case expecting to see a face, he recognizes the picture as a face right away, without at first being struck by the reduction in size compared with his own mirror-image. Here the concept of 'picture' is obviously still almost unintelligible to him, nor does he yet have an idea of his own face.

> The patient is then shown the oil-painting that he had already seen earlier; at first he confidently reports that he now has a mirror in front of him. When asked to move his head, it immediately strikes him that the picture makes no corresponding movement, and after a few further experiments, in which he waves his hand about him in various directions, and since the picture remains still, he concludes that it cannot be a mirror-image, and that he must therefore be faced with a painting.

In these cases we have an instance of the fact that pictorial content is recognized even when the concept of 'picture' is not yet understood; so long, that is, as the stock of visual images is already sufficient for recognition of the content of the picture.

RAEHLMANN II [47] is again hardly eligible here, in view of her pre-operative awareness of space, although spatial depth played little

or no part in the pictures employed. In this instance too, she shows that she had already made great use of her powers of vision before the operation. She was therefore also particularly quick in acquiring reliable images of shape. This patient was also shown the cut-out cardboard picture of a dog:

> The interpretation of a cut-out of a dog, glued on cardboard, still perplexes her greatly, though she says at the very outset that the object before her has a flat surface and is not alive.

The life-sized portrait is immediately recognized as a picture. In both cases she knows at once that it is not a real thing, and it is only the shape which causes her some difficulty, because this had hardly yet been developed in her prior to the operation.

GRAFÉ'S [49] experiment with pictures, which he only mentions in passing, was undertaken so late that his patient 'was already very well able to estimate the effects of perspective'.

In FRANCKE also [50], the experiment was very casual, and did not have much significance either, for the same reasons as in Raehlmann II.

The inability to recognize shape in pictures is equally apparent in the GETAZ case [65]:

> The first time she was handed photographs and paintings she asked: 'Why do they put those dark marks all over them?' 'Those aren't marks,' her mother explained, 'those are shadows. That is one of the ways the eye knows that things have shape. If it were not for shadows many things would look flat.' 'Well, that's how things do look,' Joan answered. 'Everything looks flat with dark patches.'

In MESMER'S case [9] it is stated (in the father's report):

> On being shown some pictures of persons with whom she was already acquainted, she immediately named the originals they portrayed. She ran her hand over the pictures and drew it back full of astonishment that the features she had supposed raised and projecting, as in a human face, were smooth and flat.

This account would contradict the findings of the other experiments; it may therefore be assumed that here the father was referring to a later stage; for in the other report, ascribed to Mesmer himself, we read:

> On several occasions she had fits of fainting, especially when near relatives or other close friends were presented to her. A similar thing happened when she saw the likenesses of her two uncles, who were both officers in the Austrian army, and for whom she had always felt a most

> affectionate regard; she ran her hand over the features of the portraits, but drew it back astonished, for her hand slipped upon the smooth glass. She fancied, indeed, that the painted features were really raised, as in living people.

This account gives no ground for supposing that the girl had actually recognized the shapes in the pictures at all. The occurrence of fainting itself suggests as much; for she would have had these attacks, not because she had recognized persons dear to her in the pictures, but because she had previously been told (just as when the people themselves were presented) who she would see in them; the hearing of these names and the knowledge that she was now at last to *see* these dear ones, threw her into this emotional excitement, and into a corresponding state of weakness, before she could really recognize anything in the multi-coloured impression of the picture. But even if she had actually succeeded in this at once, the experiment would still be suspect, because her perception had already been too strongly conditioned by her knowledge of the names and her awareness of having pictures in front of her. In this case also, however, we again encounter the peculiar imagery of the blind, who simply cannot understand how anything can possess reality when it cannot be touched.

BEER [10] also alludes to this, when he says of a twenty-two-year-old man, whom he only got to know in the fourth week after operation:

> Fortunately I was present when he was shown a very fine painting, depicting in natural size a highly realistic view of a table laden with food. Still accustomed, from his blindness, to touch everything, he now leapt up hastily towards the picture and would just as speedily have pierced the canvas with his hand if he had not been restrained, and the attempt made to explain to him that all these things he now saw were merely painted on flat canvas. But he was naturally quite unable to grasp this, and had to be suffered to convince himself of the fact by repeatedly feeling with the greatest care the length and breadth of the painting, or rather, every one of the objects depicted therein.

Thus here again we have a case where the patient has no idea that he is standing before a picture. But since, during the four weeks following his operation, he had already sat so often, with senses alert and in high spirits, at a laden table, he had long since grasped the essential features of such a table, and laid up the image thereof among his mental possessions. He even seems to have already perceived various changes in the arrangement of a dinner-table, and to possess a certain abstract concept of it, so that the notion 'dinner-table' is no longer associated in his mind with purely concrete details; this is again a sort of schema, whereby

various essential constituents in the picture enable him to recognize the significance of the whole, and also to accept the parts of the picture as something new, which he does not know from his own accustomed position at table. But since the illusion was so complete, it may well be supposed that other factors also contributed to the effect; that the whole situation, for instance, was one of approaching a laden dining-table, in respect of either time or place. The first feeling experienced by this patient on making his discovery, is again one of deception. The realization that the sighted are aware of many things to which the blind have no access, because they are imperceptible to touch, is still, in retrospect, a source of oppression to him; though he also cannot repress a feeling of wonderment:

> For a long time afterwards he still could not silence a certain fear on approaching a real laid table; for he always suspected that he was deceived, that it was a painting he saw before him, and that he was in danger of thrusting a hole in it with the involuntary groping of his hands.

The first picture given to LATTA's young man [60], at a fairly early stage, was of a head in approximately natural size: like the cases first described, this patient also attempts to find clues, not from the whole, but from the parts, and on closer inspection at length discovers the nose, and from then on has the situational schema for the other parts of the face. But from this moment onwards he is no longer a looker but a toucher; the key-word 'nose' gives him tactual awareness of the whole touch-sequence 'face'; he makes the blind man's accustomed groping movements with his fingers over the picture, and only when he thinks that he has thereby definitely arrived at a new point, does he consciously look at it and attempt to register the visual image. This method of assistance frequently led him to the wrong places. Thus in this case also, an immediate power of understanding pictorial content is not yet present, because he does not yet possess the image of a human face. Nor does he know what to make of small likenesses, because his store of memory-images provides no sort of clue to them.

2. In Monocular Vision

All the cases so far dealt with could see with both eyes. In *one-eyed* patients, however, this process of development in the understanding of pictorial representations normally progresses more slowly, because these latter, as we have already seen, or are yet to see, already have

greater difficulties in general, in registering images of visual objects and in grasping an order in visual space.

Thus CHESELDEN'S patient [5], for example, has a great deal of trouble in registering the visual images of things; his visual memory develops very slowly, because the impressions presented simply cannot be so persistent or so readily intelligible in their spatial order. During the first two months after operation he sees pictures now and again, but shows not the smallest ability to comprehend them. Only

> two months after he was couched he discovered at once they represented solid bodies, when to that time he considered them only as party-coloured planes or surfaces.

Here too, this discovery represents for him the destruction of an old scheme of thought:

> But even then he was no less surprised, expecting the pictures would feel like the things they represented, and was amazed when he found those parts, which by their light and shadow appeared now round and uneven, felt only flat like the rest, and asked which was the lying sense, feeling or seeing?

Before his operation he had taken it as an established fact that everything people saw was at least accessible to him by touch, and he found some comfort in this fact. Even after the operation, he did not at first require to correct this way of thinking; for with everything he saw he could establish a certain familiarity by touch; he thereby possessed, in touch, a sort of control-procedure for his visual impressions, a firm ground, as it were, on which he could gradually build up his new visual world. It was therefore perfectly natural in him to expect that the things represented in pictures – once he had eventually recognized them as such – could also be touched and identified by this customary means. When this proves not to be the case, he cannot so quickly accommodate himself to this discovery that a thing may appear as an object to the eye when it is not so to touch; he feels somewhat let down by this, and would be ready to welcome the news that he is under an optical illusion here; if only to escape the conclusion that his earlier scheme of things was delusive.

Two weeks after her final operation, WARDROP'S forty-six-year-old woman [16] observed, of a red wall, that its surface was diversified with pictures, and distinguished some small patches of colour in them, though without knowing that they were meant to depict shapes. Her attention lingers, rather, on their gilt frames. Wardrop adds:

> It may be here observed, that she had yet acquired by the use of her

sight but very little knowledge of any forms, and was unable to apply the information gained by this new sense, and to compare it with what she had been accustomed to acquire by her sense of touch.

Throughout the whole period, however, this exercise of vision was left almost entirely to herself, without any systematic guidance from either Wardrop or her brother. She therefore still had no established images and had also abstracted only very few basic forms from the things actually seen by her (*cf.* p. 193). In virtue of this case we do have fairly exact limits set to the development necessary prior to the grasp of pictorial representation, though the further stages in this process cannot be gathered from Wardrop, because no essential progress had yet been made by the time the lady took leave of him, six weeks after the last operation.

In FRANZ [17] we find another difficulty in the foreground:

Of perspective in pictures he had of course no idea; he could distinguish the individual objects in a painting, but could not understand the meaning of the whole picture; it appeared to him unnatural, for instance, that the figure of a man represented in the front of the picture should be larger than a house or a mountain in the background.

So far as this poses us with the problem of recognizing spatial depth, we shall have more to say of it later. It is already of significance here only to this extent, that the non-comprehension of the depth-relations shown has as its consequence, that even if he had recognized the objects depicted, which he altogether failed to do, they would merely have appeared to him completely misdrawn.

TRINCHINETTI'S two child patients [18] likewise have some difficulty in grasping the shape of a human face in pictures. This observer made his experiment as early as two weeks after operation, when the children were still trying to recognize objects by colour and not yet by shape:

When the eyes of these children were directed to pictures containing painted human figures, they did not know how to recognize them, but could merely report the main colours to be found there.

But Trinchinetti then proceeds systematically, by going on to present them with the human face in a variety of forms, and trying to get them to understand it: he first makes over his own face to the children as a simultaneous visual and tactual object, then sets a cardboard cut-out, in the shape of a face, beside his own face in a mirror and next to that a head painted in high relief:

By proceeding thus I was able to give my patients an idea of the human face as it is depicted in a painting and a mirror.

SEYDEL'S ten-year-old patient [58] took six weeks before she first recognized a more or less life-size photograph as such.

> Fourteen days later, on being shown coloured pictures, she was quick and accurate in distinguishing human beings, including also their sex, and a variety of objects and animals.

Seydel could also observe in his patient

> that her perceptions were not always associated with a correct idea of the relative proportions of the likeness. In the small pictures just mentioned, for example, she began by projecting the eyes on the cheeks, and the mouth much too deep in the region of the chin.

This girl therefore behaves very much as Latta's patient did; save only that the difference of scale in the picture presented was naturally bound to produce differences in the result. If the whole business proceeded more smoothly than in the other cases, it has to be remembered that up to her seventh year the girl had still possessed quite considerable remnants of vision. The influence of this was also apparent in her rapid mastering of figured likenesses.

PART III

Vision in Depth

Historically speaking, the problem of spatial vision has predominantly been dealt with as a matter of vision in depth. The main interest has centred on the question as to how the depth of visual space is presented to the patient. This question can be approached from three different angles, according as one asks:

(1) Whether on first seeing the patient consciously feels visual objects to be at a distance from his eye;
(2) Whether he perceives differences among the various degrees of depth in visual space;
(3) Whether he perceives spatial objects as solid structures having a certain extension in depth.

In itself it is conceivable that a patient's first visual experiments, which are the only ones that matter in answering this problem, might be so arranged as to allow these three questions about his first seeing to be examined quite independently of his grasp of shape; and this the more easily, because visual objects do in fact take on shape-characteristics for the patient only at a relatively late stage. Only in such isolation could a pertinent answer be obtained. In practice, however, numerous difficulties have emerged, and it has commonly occurred in consequence that the first visual trials have been wasted, with little or no result.

The first difficulty, seldom overcome, has been so to choose the moment of the first visual test that the eye treated is no longer subject to irritation, and so to regulate the external conditions, especially the amount of light, that a genuine act of vision occurs at the first trial. This can certainly be achieved at once only in a few cases; but when such a trial has thus miscarried, no questions should be put at all; the whole test must be completely discarded, as such, lest questioning should already set the patient off on some definite line in his thinking about vision. If, in spite of this, he has already had a conscious experience of seeing at this first abortive trial, one can let him recount it, on

repeating the experiment under more favourable conditions, before putting questions of one's own.

The source of the second difficulty is that since the patient has acquired no true conception of spatial depth during his period of blindness, he simply does not understand questions about it; a number of observers have, in fact, concluded from this that it is preferable not to ask questions, but to engage the patient in actions, so that from the manner of his performance one may go some way towards answering the three questions about spatial depth.

A third difficulty, which again has often led to obscurity in the evidence, is that the first questions cannot be so framed in advance that their wording already presupposes an experience. Thus as soon as a question is so put, for example, that it involves an assessment of the precise spatial depth of concrete objects, a negative answer is all that can be expected, though it is of no significance at all for the problem in question.

In consequence of these difficulties, the outcome for the problem of visual depth is mostly rather slender in any one case; moreover, the questions have often been put only at later sessions, when perception of shape was already no longer in the initial stages, and a certain knowledge about the nature of visual objects was therefore already possible. Taken as a whole, however, statements are available in sufficient numbers, and under sufficiently reliable experimental conditions, to provide an adequate overall picture.

I

WHETHER OBJECTS ARE SEEN AT A DISTANCE

It is only the answer to our first question which is ultimately crucial to the problem of visual depth; for the other two already incorporate issues about perception which are calculated merely to obscure the nature of the first. We must therefore concern ourselves primarily with this first question alone, namely whether the sensory impression of visual objects is also accompanied by an impression of their spatial separation from the seeing eye, so that already at first sight the patient gets, if not a consciousness of spatial depth, at least a more or less clear impression to that effect. For he cannot be expected, in this first act of vision, to be already quite clear that the visual objects he thereby discovers are too far away from him to be within arm's reach; since from touch alone he simply does not possess the presuppositions for such a sudden and radical change in all the conditions of his acquaintance with the environment. His thinking is at first entirely unprepared for any such possibility of perceiving objects beyond arm's reach.

It is obviously of the greatest importance to bear this in mind when considering the first statements made by the patient. It is likewise necessary to rule out from the start in these utterances, everything which already extends in any way to an estimation of depth. On the other hand, it is naturally no less indispensable to weigh up just how much in these statements already relates, as it were, to pre-operative visual experience. This was the reason, indeed, why we have already segregated earlier those cases which are of less relevance to the following discussion of the problem of depth in visual space, because they were already to be reckoned among the sighted prior to operation.

1. The Cheselden Case (Visual Objects 'Touch' the Eye)

The first person – in appearance, at least – to concern himself with the problem of visual depth was Cheselden. In spite of the obvious defects

of his report, for which he cannot himself be held responsible, it has exercised very great influence; first because his findings appeared to provide a more than sufficient confirmation of the predictions published by Locke and Berkeley a few years before (1709), and secondly because, for many decades, this case remained the only one to have been investigated in detail, and so for the time being appeared irrefutable. It has become the truly classical case, repeatedly referred to even up to the present day. It must therefore, be dealt with in some detail.

The main controversy centres on the words:

> When he first saw, he was so far from making any judgement about distances, that he thought all objects whatever touched his eyes (as he expressed it) as what he felt did his skin.

The first thing that matters in this controversy is to establish Cheselden's own position in regard to these words; for this will determine what weight one ought to attach to them. Now this is, in fact, the only passage in his report where he expressly cites the actual words used by this thirteen-year-old boy. The phrase in brackets ('as he expressed it') has curiously been omitted by Helmholtz in his reprint of the report in his *Physiological Optics*; its meaning is merely that Cheselden wished to indicate that, as they stand, he did not find the content of these words immediately acceptable – that he is quoting them rather, as an oddity, and at all events wishes to guard himself against being saddled with this expression as a phrase of his own. The same is also shown by the choice of the words 'he thought'.

Now it would naturally have been desirable to check this statement by suitable experiments. Since Cheselden did not do this, the question arises whether he was altogether aware of the import of this remark, or in other words, whether he was acquainted with the problem attacked by Locke/Molyneux and Berkeley. This question seems absurd, when it is remembered that this discussion, and Berkeley's publication on the subject, occurred during Cheselden's own student days in London and if one also recalls that Locke and Berkeley belonged to that same influential and highly-respected 'Royal Society of London' (founded 1645) to whom Cheselden submitted his report. And yet the question seems justified when we read his biography in Morand (*Éloge de Cheselden*) and there learn that he undertook this operation in a largely impromptu fashion, since the case attracted him for its own sake, as a surgical problem; but that apart from that he had only rarely been concerned with operations on the eye. It may also be noted that he does

not mention any of the above authors, whereas all later writers have expressly alluded to the controversy in question. Thus, if he had been acquainted with the problem, one might have supposed that he would either have tested this assertion by experiments of his own, or would not have referred to it at all. Hence it would certainly appear that these words have become associated with this problem without any design on Cheselden's part. This also seems to emerge from the whole character of the report in general, which merely gives a brief enumeration of a few medical data and some psychological details that had particularly struck him, without attempting to theorize about them. The report reveals that Cheselden wrote it down from memory, without benefit of notes, only after the second operation, which took place about a year later; and that in doing so he may well have deliberately avoided taking up any position on the problem of spatial vision, on which, moreover, he scarcely claimed to be an authority. One may say, indeed, that apart from his opening sentences, Cheselden has in general only reproduced the thoughts of his young patient, without comment of his own; and in the passage in question he has actually reported his words *verbatim*.

From this it may be inferred, at any rate, that Cheselden himself was far from wishing to put these words forward as the literal truth; that at all events he did not credit them with the significance subsequently attached to them as the foundation of the empiricist theory; and it is questionable whether he was himself entirely clear, in general, as to their possible implications.*

These words therefore stand entirely on their own, as an expression of the subjective opinion of the thirteen-year-old boy, and it remains merely to ask, what can have caused him to utter them. Here it is wholly idle to excogitate from the sense of the words whatever he may possibly have intended by them; one has, rather, to take them as they

* Thus Berkeley, too, seems neither to have had previous knowledge of this case, nor to have influenced Cheselden, although his attitude might appear to suggest this. For Grant's patient, who was operated on in 1709, shortly before the appearance of the Second Edition of the *New Theory*, is mentioned only briefly at the end of the Appendix to this edition. But although the report of the case in the *Tatler* must have tempted him to get in touch with Grant – because it was not in fact perfectly suited to confirm Berkeley's theory – he does not mention this case again, but at the end of his *Theory of Vision Vindicated* quotes instead the central passage from Cheselden, and observes in conclusion:

'Thus, by fact and experiment, those points of the theory which seem the most remote from common apprehension were not a little confirmed, many years after I had been led into the discovery of them by reasoning.'

were spoken. The only question is, what they were actually meant to refer to.

The first thing to strike one is that Cheselden speaks of a 'judgement about distances'. This is already enough to show that his questions were completely improvised, in so far as he put them about estimates of distance, which it was impossible for the boy to have answered and whose meaning he probably did not even understand at first. Since, moreover, at first testing, the boy could scarcely have had any sort of adequate notion of 'distance', and since he could equally have had no inkling of this quarrel about the theory of spatial vision, it cannot be supposed that by these words he was in any way seeking to affirm that visual objects appeared to be at zero distance from his eye.

It has to be assumed, rather, that these words were occasioned by a definite perceptible stimulus. The latter must doubtless be construed, not so much as the pain resulting from the incision, since he had felt that all along, but as a pain caused by his sensitivity to light, which Cheselden expressly mentions, and which is also complained of by the majority of the other patients.

It is only too intelligible that the boy should have failed to identify the light as the source of this pain, and should have supposed, rather, that it was a natural consequence of the fact that the objects seen were in contact with his perceiving eye; for touch, hearing and smell had given him no reason to suppose otherwise than that the perception of an object must be accompanied by an impression of touch at the point of contact, or in the perceiving organ.

Mill (18) says of this passage from Cheselden:

> [His patient] simply transferred the experience of touch to the newly-acquired sense. All his notions of perception were associated with direct contact; and as he did not perceive any of the objects of sight to be at a distance from the organ by which he perceived them, he concluded that they must be in contact with it.

The latter is already a piece of empiricist theorizing; for it is simply not probable that the boy should have drawn a reasoned conclusion of this kind.

There is, in fact, no discovering what the boy actually saw at this first test of vision, because Cheselden gives no definite details, and does not even tell us, for example, what period had elapsed between the operation and the first visual trial, or how far the operated eye had recovered by then. For when he says:

> He knew not the shape of anything nor any one thing from another, however different in shape or magnitude,

this statement is so much in conflict with all the others that there is reason to assume that in fact – with his high degree of amblyopia, and lacking either lens or spectacles – the boy's vision was so blurred that, even in an objective sense, differences of shape were not sufficiently clearly presented to him. But this would be only one more reason for concluding that this first trial simply cannot be regarded as a trial of vision, since the boy did not receive any normal visual impression, and hence only reported the sensation impinging on his eye.

Such being the case, it would anyway have been an error for Cheselden to have connected this statement with visual depth in general, even if he was not prepared to vouch for its factual correctness. This failure to distinguish shapes might have alerted him to the hopelessness of then inviting him already to make 'judgements' about distances in general. Thus we obviously have, on the one side, questions framed in error, and on the other, a complete inability to understand them.

Yet this much is clear at all events, that there was every occasion to ponder these momentous words with great care in regard to their real content, and not to apply them without further ado as the basis for a theory of visual space; for, without more extensive justification, they could not claim to tell in any direction, and were plainly not thought to do so by Cheselden himself.

The patient's exceptionally laborious learning of visual images by heart suggests, rather, that his powers of vision only developed very gradually; it would even appear, indeed, as though he did not acquire a real understanding of the extent of space until his second eye was operated on, a year after the first.

In general, therefore, we cannot at any rate dismiss the impression already voiced by Janet (5):

> Everything depends on a single word; one is bound to admit that it would be difficult to erect a theory upon any more slender foundation.

2. Other Evidence for this Theory

Let us now go on first of all to consider those cases of which it is maintained, in supposed *agreement with Cheselden*, that on first seeing the patient has the impression that visual objects touch his eye; and from which the conclusion is drawn that vision does not carry with it *a priori* any sense of depth. The first thing to strike us here is that although this passage from Cheselden has been constantly quoted, and every conceivable inference extracted from it, the cases where similar findings are

reported are comparatively rare, and not one of them is in any way conclusive for the theory based upon them.

A very striking indication of how the idea may arise that visual objects touch the eye, is given in the short report by NUNNELEY [21]. For in this case it is merely a matter of a sort of *idée fixe*, due to the patient's long-continued habit, when making a closer tactile examination of objects, of also holding them to his eye before giving a final judgement as to the nature of the object in question. But since, before operation, he could effectively perceive by eye neither colour nor shape, but at best quite vague differences of brightness (darkness), the reasons for this habit, apart from these quasi-shadow effects (or production of phosphene by pressure ?), are to be looked for only in special tactile stimuli, such as the particular sensitivity of the eyelid to differences of temperature.

At all events, this habit was incorporated as a separate partial experience in the act of identification as a whole; the boy was convinced that he thereby gained some information about the peculiarities of the object under investigation, and associated this sort of imagined 'seeing' with the impression of contact on his eye. Given such an *idée fixe*, it is perfectly easy to understand his anxiety about the impact of visual objects on his eyes, because he now no longer brings things to his eye, but has a continuing contact with them by a genuine act of vision, and so also constantly expects the passive impression of contact. Thus here we are obviously concerned only with perseveration in an erroneous idea acquired under a different mode of existence.

This persistence in a mistaken idea, so shortly after the operation, is no longer remarkable when we consider how persistently these words of Cheselden have operated upon the observers of the later cases. For we also observe in Nunneley himself how, 130 years after Cheselden, he simply takes over the latter's old formula, without testing this fallacious conception by experiments of his own, and without it occurring to him, for example, that the boy makes grasping movements towards the objects presented to him in order to assist his recognition of these objects by the aid of touch. If he had likewise made these movements towards his own eye, Nunneley would certainly have noticed such a striking mode of procedure. However, the boy seems to have made such movements spontaneously only after the first visual trials, whereas previously the test-objects had been given into his hands. The few words concerning the first experiment give no sufficient indication; it seems, however, as though the boy immediately perceived the presented

objects as separated from his body, but could not understand the doctor's questions about distance, simply because, before operation, he had been unable to conceive of distance in spatial terms.

It now remains to examine how far similar ideas have also been operative in the few cases where the patients have made statements of this kind.

In Cheselden's own case, nothing further can be established, because he gives no details about his patient's manner of life before the operation.

HOME, at the beginning of his report [13], stresses his intention of clearing up the conflict of opinion between Cheselden and Ware; he obviously wished to make up for Cheselden's neglect and to test the correctness of the expression 'touch the eye'. But this endeavour to rescue the theory is all too clearly reflected in the report, in that already before operation Home had set about establishing his patient's pre-operative powers of vision by experiments devoted to this end, in which he had obviously asked the boy each time whether the light or other test-object touched his eye or not. These words had been so drilled into the boy that he kept on repeating them after operation on every possible occasion, where they were quite out of place. We have already discussed this case in connection with the space of touch, and there concluded that the boy's introspective observations were perfectly in keeping, but that Home had taken his words in a sense different from that intended by the patient. But in this very case there can be no possible doubt that the boy had already possessed a visual awareness of space before operation; at all events he must have acquired one by these experiments, even if he had not possessed it before. For even before operation, Home, by his whole approach, had so far accustomed him to vision in depth, and so thoroughly initiated him into the whole problem, that so far as the post-operative tests were concerned, he had already forfeited his innocence, and was habituated in the use of a specific technical term.

This case would in any event have been useless to our inquiry, because the patient's vision had been so far practised before operation that he had, for example, already overcome the nystagmus he had had as a child, and could converge his eyes, fixate upon an object and probably even accommodate (though Home does not mention the fact). Thus, for the post-operative visual tests, he already possessed some visual standards of comparison, knew some criteria of depth, and did not first need to acquire them.

This shows up all the more clearly the unnatural, preconditioned nature of his responses after operation. So much can already be seen

from the wording of his answer to the first question. When Home asked him what he had seen, the boy answered:

> Your head, which seemed to touch my eye.

No twelve-year-old boy frames such a sentence, provided he can speak in a natural fashion. Thus, if he actually used these words, or something like them (which seems more probable), then (1) he was merely repeating what had been said to him a dozen times before, and (2) he also meant something different here by touch from what Home wanted to discover in terms of this expression; probably, as with Cheselden's patient, the sensation of pain in his eye (which Home also refers to). For if he already had an impression of depth before operation, when converging on a candle-flame held in front of him, he cannot well have forfeited his depth of vision in consequence of the operation. Only when the left eye, the first to be operated on, developed an opacity in the cornea, could there have been any impairment of his vision in depth, so far as it was binocular in character; and on that occasion the boy said exactly the opposite. This equally leads one to conclude that, in his first remarks after operation, the boy meant something different from what Home took his words to express. The whole case, therefore, really amounts to no more than an abortive attempt to reinstate the theory associated with these words of Cheselden's patient. For there can really be no doubt that the boy saw visual objects at an indefinite distance.

FRANZ [17] makes only the very general observation, that when his eighteen-year-old patient first saw, all objects appeared to him so near,

> that he was sometimes afraid of coming in contact with them, though they were in reality at a great distance from him.

But again, as with Cheselden, this is only a false *estimation* of depth, not a lack of vision in depth altogether. For when, on the fourth day of testing, this young man remarks (when looking at a mirror),

> that he was always obliged to bear in mind that the looking-glass was fastened to the wall in order to correct his idea of the apparent situation of objects behind the glass,

we simply could not wish for a better example of vision in depth. Later it is said:

> If he wished to form an estimate of the distance of objects from his own person or of two objects from each other without moving from his place, he examined the objects from different points of view by turning his head to the right and to the left.

Such a procedure could likewise only have meaning if the patient was quite clearly aware that the object in question was spatially separated from him. That this awareness of depth was also present at the first visual test (monocular), can be seen from the following:

> On opening the eye for the first time on the third day after the operation, I asked the patient what he could see; he answered that he saw an extensive field of light, in which everything appeared dull, confused and in motion. He could not distinguish objects.

(This motion of all visual objects then turned out to be a non-optical appearance of floating spheres, which gradually disappeared.) This statement definitely has greater probability in itself, since it emanated from an educated man (the son of a doctor) whom Franz credits with

> an excellent understanding, quick power of conception, and retentive memory,

and who was plainly accustomed to rendering a trustworthy account of his impressions.

Again, in the first systematic visual trial, once the eye had restored itself (after the disappearance of all non-optical phenomena), in which Franz made use of coloured silk ribbons on a black board, nothing is said which might lead one to suppose that the young man had not seen this board at a certain distance.

TRINCHINETTI [18] expressly refers to Cheselden, and undertakes an experiment to test the statement in question, by holding up an orange before his two ten- and eleven-year-old patients and first making sure that they could see it. He then says:

> But when I told him to take it, he raised his hand so that it almost touched his eye, and there clenched his fist, which he was astonished to find empty. When I told him to repeat the experiment, he stretched out a hand at a distance of several inches from his eye and here renewed his attempt to grasp the orange. I then decided at once to make the same experiment with the girl; she too at first attempted to grasp the fruit with her hand quite close to her eye; but immediately on perceiving her error she stretched out her forefinger and directed it slowly in a straight line from her eye towards the orange, until she was able to touch it.

Both patients performed this experiment with the left eye only, i.e. under monocular conditions. Trinchinetti sums up his opinion as follows:

> I am therefore convinced of the fact referred to by Cheselden, that as soon as these patients have gained their sight, they believe that objects touch their eyes, though experience soon relieves them of this error.

But since this statement stands on its own, the actual content thereof must be examined, to see whether the experiment as such was beyond criticism. Trinchinetti allowed both children to handle the test-object beforehand,

> to make sure that they would at once recognize it again later;

hence, in reality, this experiment was not in the least calculated to determine whether a given object is consciously seen to lie at a certain indefinite distance, but was concerned, rather, with estimating the specific depth of an object already examined by eye and touch, coupled with the task of executing motor behaviour in accordance with this estimate.

Since the children did not make their accustomed movement of stretching their hands out, but on the contrary brought them close to their eyes, they must indeed have had an impression of close proximity; and the question now is, how they arrived at this impression. One might first consider such specifically visual factors as the constricted field of vision and the effects of blurring and enlargement due to diffusion, whereby the orange might have appeared especially prominent to their view. But Trinchinetti makes no mention of this; and since, in any case, this result was manifested simultaneously in these two cases alone, but did not lead to spontaneous behaviour of this type among the other one-eyed patients, it seems that some other impressions must have been operative in this instance, which Trinchinetti failed to detect. And indeed it was very probably smell which was responsible for so definite an assumption of close proximity, and the disappointed astonishment at not grasping the orange, or which at least had an effect upon the judgement. For having touched and smelt the orange at close quarters, they would have been especially receptive to this sensation of smell. We have already encountered many such cases, indeed, and will meet with still others later on, in which seemingly inexplicable experimental findings receive a perfectly natural explanation in this manner.

One might finally put forward the passage from ALBERTOTTI [39]:

> When the tram started, he said to me *en route* that the lights were approaching him; that some of them were skimming and almost touching him; and as if to shield himself against them he first stretched his hand upwards and then quite quickly drew it back again.

Albertotti took this trip with his patient before the operation; and here, as with Home, the supposed impression of contact was doubtless due to a dazzling effect; the impression of lights approaching was

occasioned by the rapid increase in brightness when on the move; the degree of brightness has become a sort of substitute-image for proximity; and when it is so strong that it dazzles the eye, the pain gives rise to an impression of the light as within the eye. Thus it is also recorded of him after the operation that,

> On viewing a lighted candle in the darkened room, he said there was a light in his eye.

The whole procedure here is very unrealistic, for of all objects a candle would seem to be the least suited for such primary visual testing. Nor is it evident why Albertotti always insisted, for example, on the use of only one eye at a time. He was manifestly unlikely to awaken any great enthusiasm for seeing in his eighteen-year-old patient by these laboratory methods, and this was to be regretted, because under his guidance the young man had already become very receptive before the operation.

3. Statements against the Theory

Among those cases who already had both eyes available for primary visual testing, there is not one who made any such statement in confirmation of Cheselden's view. On the contrary, there are also several even among the one-eyed who were equally positive in *repudiating* this supposed *impression of contact* with the eye.

Thus DUNAN [42] speaks of a 'generally accepted legend' remaining obstinately alive in spite of all evidence to the contrary. Dunan could not make this thirteen-year-old girl patient of his understand the meaning of the word 'depth' and infers the effect of vision in spatial depth from her attempts to judge distances in order to facilitate her gropings towards objects. The estimates were naturally false, but led none the less to movements that must be regarded as atypical in comparison with normal touch-procedures, and therefore presuppose a conscious localization of visual objects in space. Thus, at her first visual test, she overestimated the distance of an object shown a foot away, and reached beyond it, while with the other objects she fell short. Dunan sums up:

> Thus she saw all objects at a certain distance, though it was probably indefinable to her, because we could not get her to say anything on the subject; but for all that she saw them projected in space.

And later he again says:

> From the case of Marie V. we may regard it as proved that a person whose eyes are opened to the light for the first time immediately sees

the plane extensiveness of space, together with relations of size and situation among shapes, and recognizes the various planes in which objects are spaced off, but finds pictures to be likewise projected as if in space, though at distances as yet indefinable.

LEPRINCE also [63], whose case had so far had only one eye operated on, says:

As regards spatial vision, he never conveyed the impression of Cheselden's blind patient, that objects were in contact with his eye. He entered into possession of the space beyond the limits of his reach on the day an orange was put into his hands and he amused himself by rolling it on the floor.

Another one-eyed patient, that of HOME II [14], when asked directly whether he had the impression that objects touched his eye, also gave a negative answer:

He said 'No', but when desired to say at what distance it was, he could not tell.

Thus here, as with Cheselden, we again have a confusion between matters that are not interconnected in primary vision. In any event, this case must be excluded, since owing to his limited powers of vision this boy had already acquired a certain awareness of spatial depth before operation.

WARE made control experiments on two congenitally blind children of seven and eight, who had not then been operated on, and comes to the conclusion:

Nor have either of them the slightest suspicion, as is related of Mr Cheselden's patient, that coloured objects, when held before them, touch their eyes.

But this statement is of no effect either, because here too the first conscious visual experiences had probably occurred long since, so that vision in depth might also have been acquired thereby.

4. Neutral Statements

In the vast majority of cases the findings of the first visual tests fall midway between these two extremes; thus there is *no definite claim* that visual objects appear to touch the eye, but also no formal denial of this.

A. MONOCULAR CASES

Chief interest here attaches to the *one-eyed* cases, since in addition to

lacking the power of accommodation, the other spatial factors are also of no effect, so that what is actually tested in their case is whether, on first seeing, without these aids and without experience, the single human eye receives a spatial impression of depth.

Here we must naturally disregard once more the cases who already possessed a visual awareness of space before operation, though this is itself an indication that one eye alone is sufficient for external vision.

In WARDROP I [15] vision in depth was present from the start. But Wardrop's experiments were so casually conducted as to be open to the legitimate objection that this patient's awareness of the distance of visual objects was given to him, not so much by their appearance to the eye, as by the passive impression of feeling which the heavy objects (such as a book) must have exerted on his body through the bedclothes; so that the groping movements towards the items presented were guided by this familiar impression of feeling and not by any visual image of the object. Wardrop seems himself to have supposed that this correct estimate was obtained by purely visual means; he could not question his patient about his impressions, since the boy was a deaf-mute.

From HIRSCHBERG also [24] we get no clear picture. For the first visual experiment, by candlelight, tells us only:

> I moved my outstretched fingers to and fro some eight or ten inches before his eye, and asked him how many fingers he could see. He answered after some hesitation, and not always correctly. For all that, he saw the fingers, and directed his gaze towards them.

The first experiment directed to spatial vision was again concerned with the estimation of depth, and was in any case only administered rather late, after Hirschberg had previously explained to him the spatial lay-out of things in the garden outside the window, and had already given him a clue, on the first day of testing, as to where to look for visual objects, by taking the boy's hand and leading it to his own brightly illuminated nose, on which the boy's eye was fixed at the time. When first showing the boy his fingers, he would have done better to ask him to take hold of them so as to combine the two processes together; though he would have had to dispose his instructions in such a way that he did not thereby provide an unintended clue.

In VON HIPPEL [23] this experiment was more successful: at her first consciously undertaken visual test, which owing to inflammation and other circumstances could not be conducted until seven weeks after

operation, the four-year-old girl was shown a handkerchief eight inches away, which she described as bright:

> To the question, whether the brightness was near or far away from her, she replied: 'Far away, but you can reach it.' When I slowly withdrew the handkerchief, she followed it with her hand.

It is significant here that she uses the words 'far away', which before the operation meant much the same to her as 'out of reach' or 'a long way to go', but which she now applies quite correctly to the spatial. The words 'you can reach it' suggest that she seems to have felt this change of meaning herself; at all events, the child is at once aware of spatial depth, and also has a clear impression of change of depth, without as yet having gained any experience of visual depth, variation in apparent size, etc., and although she had only one eye available and could not accommodate.

In DUFOUR [26] the twenty-year-old patient likewise took some days before he attained any notion at all of seeing, so that the experiments undertaken in the first few days did not point to any particular conclusion. But as soon as he consciously began to use his sight, he also showed a clear awareness of depth, in that when instructed to do so he made groping movements towards shown objects, though without recognizing them by sight. Unfortunately Dufour gives no further details of these gropings. As was already pointed out in the case of Dunan (*cf.* p. 229) it is naturally doubtful, in all such experiments, whether the patient has not still been making these groping movements entirely in the accustomed manner of the blind. For if so, it might be said: the blind man is in the habit of establishing contact with tactual objects by extending his arms, slightly bent, in front of him. If now, at the first visual trial, he stretches out his arms in exactly the same fashion, one may well suspect a perseveration of touch. Such behaviour would then be neither a proof against the view that when seeing he is not in fact localizing the object at his eye; nor a proof in favour of the opinion that he consciously localizes visual objects at a certain as yet indefinable distance; but merely an indication of the fact that throughout this experiment he has not yet consciously reacted to the visual impression.

In this particular case of Dufour, the question cannot be decided, since the details are too scanty. An extended landscape at a considerable distance seemed first presented to the young man as a vertical pictorial surface at a certain uniform visual depth, though he could not single out from it any one visual object.

Two months after the operation, at a session of a medical society, he was already quite accurate in his recognition of arrangement in depth within his immediate visual environment; but this cannot be relied upon here, since by that time the patient was obviously employing auxiliary criteria of his own (for example, visual size).

WARDROP [16] also made no systematic tests with his second case, of the forty-six-year-old lady, and his remarks are again quite indefinite. Despite this, it emerges from his report that immediately on first seeing his patient had an impression of depth:

> The operation being performed at my house, she returned home in a carriage, with her eye covered only with a loose piece of silk, and the first thing she noticed was a hackney-coach passing, when she exclaimed, 'What is that large thing that has passed by us?'

It will be noticed here that she could already have been guided as to the nature of the object by hearing the sound of the wheels, if she had paid attention to this. Thus she had either forgotten to notice and evaluate her customary impressions by reason of her great interest in her new sense, or had indeed noted the sound but failed to relate it to the visual impression. But the latter would indicate that the impression of hearing had not given her the spatial direction of the sound; and that she did not possess any notion of the shape of the carriage she had so often heard and made use of.

In SCHMIDT-RIMPLER'S case [37], the boy (aged three years and four months) at first stretched beyond the objects. But since he had only been blind for a year, we cannot take this case into account here. For even if he had lost all recollection of shape, he obviously still knew the use of his eyes and still had a certain remnant of vision, for shortly before the operation he stretched out for a knife held before him, attracted by the visual impression.

B. BINOCULAR CASES

The patients who could already see with *both eyes* at the first visual trials, show a great many signs of the fact that visual objects at once appeared to them at a certain visual depth. Even where the exact course of these first trials is not described in detail, the reporters still make mention of the impressions they received at the time.

The first to set up in conscious opposition to Cheselden was DAVIEL [7], whose experience of twenty-two cases led him to write:

> As soon as they began to see, they stretched out their hands ahead of them in a direct line from their eyes; their perception was therefore

external, being occasioned by the presence of the object and not by the image cast upon the *fundus oculi*.

JANIN [8], who quotes this passage, and likewise bases himself on thirteen cases, says of the twenty-two-year-old girl on whom he reported in detail:

> She had not yet been able to orientate the inner perception of her organ upon that which was occurring outside: and yet, as soon as she saw any object, she stretched out a hand, always in the direct line of sight, in order to grasp and recognize it by touch.

In another passage he says:

> The sensations felt by this girl on the presentation of objects, did not in the least incline her to suppose that they touched her organ of vision, but rather that they were situated at a certain distance; she also extended her hand to a greater or lesser distance from her eyes, though never sufficiently far to reach the objects.

The description of the first visual test does not reveal whether Janin took particular note of the point so early as this. After the operation she closed her eyes at once, being dazzled; the first experiment was then undertaken, fourteen days later; she too was at first very frightened at the sight of a candle-flame. The candle was then put behind her, and after a quarter of an hour she was again persuaded to open her eyes:

> The more she now directed her gaze upon everything about her, the more it could be seen how an expression of gratification and astonishment overspread her features; she repeatedly exclaimed: 'Oh God! How beautiful!' But she did not recognize any object.

It may be wondered how she was led, in grasping at objects, to set out from her eye; no doubt this also involved an idea, based on touch-experience and so natural to her, that the eye must somehow have a direct relationship to visual objects; and hence the conviction that if so, it would be advisable, when approaching them by hand, to start from the eye. But since in so doing she always began this approach at a certain distance from the eye, varying according to the impression, she must thus have had a perfectly clear impression of depth. It is shown by Janin's own words, that she

> extended her hand to a greater or lesser distance from her eyes,

and in general raised the hand to this height, that she was consciously guided in her gropings by the visual impression.

In this context we may also mention a passage which Janet (5) takes over from Maine de Biran (no reference given), and which the latter

quotes from a work by Rey-Régis (pseud. of Cazillaq), *Histoire naturelle de l'âme*, Paris 1789; it relates to another case of Janin's, not included in the report we have examined:

> This patient, whose eyes were opened by Janin, saw objects neither double, nor reversed, nor touching the eye. . . . This same girl, like some of Daviel's cases, stretched out her hands to objects in order to grasp them; thus she had a certain idea of distance, of extension.

RECORDON [20] does indeed endorse Cheselden's theory, but errs in doing so, because his experiments related to *estimation* of depth and not to the simple question whether an impression of depth was present on first seeing. He then himself says that he would not be prepared to found a theory on his observations. But in fact there must already have been an impression of depth when, seven weeks after operation, his patient first saw a house and a tree; if only because, on Recordon's own showing, vision was established gradually, so that there was also no avoiding a gradual acquisition of experience.

SCHNABEL [33, 34] does not refer to the problem of vision in depth, and the details recorded of the first visual trials are somewhat sketchy. But since, for a start, both patients followed a moving object with the head, there must have been an impression of depth in these cases also.

In the case of FISCHER'S eight-year-old girl [44], the cataracts only developed gradually from birth onwards. She had indeed lost any visual idea of shape, but seems, however, to have retained a certain awareness of depth. She only had nystagmus in the early stages, and was at once able to fixate, with eye-movements coordinated, nor was she hypersensitive to light. On the first day of testing, we are told:

> With her back turned to the window she opened her eyes spontaneously, in spite of the bright autumn daylight flooding the room, and directed her gaze without much difficulty to the objects held before her.

On the second day of testing Fischer already says:

> She seems to be orientated as to the direction and distance of objects about a foot away, since she never grasps beyond or beside them.

This case also is therefore of little value to our inquiry.

UHTHOFF I [45] reports:

> When the tests begin, the patient grasps at presented objects in a very uncertain and hesitant manner. He does indeed grope more or less in the direction of the object with his hand, but his errors of distance are quite extraordinary.

We may again disregard this inaccurate estimation of depth. But the

impression of depth itself is immediately present, the gropings into visual space occur spontaneously, and although uncertain they are none the less consciously directed towards the visual impression of objects; so that we cannot be said to be dealing here with the customary groping of touch. Since Uhthoff was extremely thorough in describing his cases by means of day-to-day reports, he would undoubtedly have noticed if his patient had localized visual impressions in his own eye.

In his second case, as also in a case of temporary amaurosis due to spasm of the eyelid, Uhthoff again gives no exact account of the early moments of vision, and throughout his cases plainly did not have these fundamental problems in mind.

By contrast, in RAEHLMANN I [46], the first trial of vision turned out very well. Raehlmann first spent a minute in confronting his nineteen-year-old patient with the object, his own drinking-mug, in order to give him the opportunity of bringing his eye-movements more or less under control. The young man is anxious to see, and succeeds in doing so; he is so earnestly preoccupied with this first visual object that even at the first attempt its visual appearance remains lodged in his memory.

> On being told to grasp the object, the patient carries his right hand from the side of his body upwards and forwards across the chest, passing slowly and cautiously to one side of the object, too far forward, then back, and finally grasps it with his fingers, whereupon he declares it to be his mug.

Here too, therefore, we have, not a groping in the manner, and at the distance, of his earlier tactual explorations, but a deliberate advancing of the hand, making conscious use of the visual impression, which apprises him beforehand of a spatial depth. The impression of this is so pronounced, indeed, that he also perceives the differences of depth between his cautiously advancing hand and the motionless object, and can adapt his further movements accordingly.

GRAFÉ'S statement [49] would also have been significant if he had been in a position to check up on it, two months after the operation. He says:

> I asked him whether at first it did not seem as if the walls and furniture about him touched his eye, whether he had not seen in a uniform plane, without hollows or protuberances, as in pictures, for example, which I showed him, and in which he could judge the effects of perspective very well. He simply did not understand the meaning of my question, and could only keep repeating that he had always perceived objects at a definite spatial distance, just as he perceived them now.

Grafé further endeavours to support this statement by the testimony

of those who had looked after the fifteen-year-old boy in the early stages:

> Neither Bribosia (the surgeon) nor the matron, nor any other of the persons who have cared for the patient, have seen him holding his hands before his eyes in order to ward off objects pressing in upon him. From the first moment onwards, indeed, he stretched out his hands to grasp objects more closely or to use them (e.g. for eating).

It is now a question, what attitude should be taken to these suggestive inquiries; it could rightly be objected that after two months the boy would no longer know anything at all of the learning-process he had undergone, and could therefore have persuaded himself that his statement was true.

In FRANCKE [50], vision in depth was self-evidently observable immediately after the operation, because his patient was one of those who had already possessed a visual awareness of space before it. There is therefore no occasion for Francke to attribute the correct estimates of distance to the superior intelligence of his patient. This higher degree of intelligence had already been manifested before operation, in that, unlike other cases, he had realized how to make the best possible use of his sensitivity to light, especially in relying on visual impressions to give a more spatial form to his tactual experiences than they could have had without this assistance.

In AHLSTRÖM [51] the nine-year-old girl made her first visual experiments on her own fist:

> But after a time, this hypersensitivity to light disappeared, and she began to look around the room. The first things to attract her attention were her own hands; she looked at them very closely, moved them repeatedly to and fro, bent and stretched the fingers, and seemed greatly astonished at the sight.

Here, the first act of vision is much intermingled with tactual thought-processes; in spite of that there can be no doubt of the occurrence of a visual impression of depth. The whole process can readily be reconstructed and broken up into separate phases: (1) great distress at the light, coupled with the realization 'you can now see'; (2) the desire to try out this new ability finally overcomes her anxiety, and the eyes open to look about the room; (3) she receives visual impressions, and is already aware in doing so that visual objects are spatially separated from her (to which knowledge and the tactual space-schema may well have contributed), but cannot interpret the impressions she receives; (4) a chance movement of her hand reminds her that she has already often puzzled

her head about its appearance; the hand is under her own tactual control; she knows that she will now see it if she brings it to her newly opened eyes; and this will be some comfort, in view of her earlier degree of perplexity in seeking to understand her visual impressions; (5) she goes through the motions of stretching out the hand in her normal blind fashion, opens her eyes, and reassures herself by tactual movements of the fingers as to whether it really is the hand that she has in view. The two activities are not yet coordinated; the stretching out of the hand is one independent act, and the seeing another. Throughout this fascinating interplay of kinaesthetic and visual sensations, spatial depth is not registered as a separate impression, but is simply there.

This juxtaposition of touch and sight in the first period after operation is still more clearly in evidence in VURPAS-EGGLI's case [52]. During the first eight days after operation, neither of the boys evinced any psychological reaction to visual impressions. On the eighth day after removal of the bandages, we are then told, of the elder, five-year-old boy:

> When presented with an object, he made no use at all of his eyes in order to grasp or skirt round it, but turned his head away, stretched out his arm, touched the object from every angle and applied his tongue to the surface. We then made the following experiment: we showed him a cake, which was ostentatiously laid in front of him on the floor, and he was told to take and eat it. All happened just as before; he searched for it by touching *à l'aveugle*, as it were, but made no use at all of his eyes, either to assist his own movements or to guide himself as to the direction of the cake. . . . On the second experiment, we deprived him of the use of his hands and thereby actually got him to perceive a cake lying within his reach, which he would thus have been perfectly well able to see anyway. But no sooner was he allowed the use of his hands again, in order to pick it up, than he at once averted his eyes, turned his head away, and got hold of the cake by tactual groping, exactly as before the operation.

The last scene in particular is very characteristic; here we have a perseveration of touch due to pure stupidity. The child is acquainted of the presence of an object by sight, but then stretches out his hands in precisely the usual fashion; thus when grasping in depth he is guided, not by the visual impression, but merely by the visually acquired knowledge that there is an object in his vicinity. This movement is executed quite mechanically, in accordance with the familiar experience that everything perceived can be reached by this stretching of the arm. He has no visual conception of 'distance' at this stage, since he is not yet

making any conscious exercise of his vision at all. Only in the second experiment does a visual awareness of direction seem to have been operative, whereas in the first, the boy searches out a whole area in his accustomed fashion, without either at once pursuing the direction of his search correctly by the initial visual impression, or later amending it by taking a second look.

In subsequent experiments the younger child stretches out his hands, indeed, in the approximate visual direction, but always to the same distance, in accordance with the customary muscular sensation, regardless of whether the presented test-object lies within or beyond arm's reach. In this case one cannot say that there is merely a false estimate of a specific distance, as in the cases previously dealt with; for here the problem of visual depth plays no part at all, since in his general motor behaviour the boy is still predominantly a toucher.

In SEYDEL'S case [58], the ten-year-old girl was only put under instruction three weeks after operation, but, left to herself during that period, without any initiative, she had not yet tried to learn anything from her visual impressions:

> She behaved exactly as before the operation, and so could still be regarded as one blind; one could pass large, bright objects before her eyes without producing the slightest effort to focus them.

(This is by no means an isolated instance: MINER'S case [59], a twenty-two-year-old girl, had not succeeded in making much more of her powers of vision two years after the operation.)

Seydel endeavoured to sound the child as to the presence and nature of any surviving visual memory-images, but completely without success; though the girl had only gone blind some three years before.

> She behaved as though completely blind, bumped into everything, would only move forward groping cautiously with outstretched hands and dragging her feet on the floor. Left to herself she sat listlessly in her chair for hours at a time, face expressionless, head bent slightly forward and looks directed to the ground; even working with her hands produced no change at all in the direction of her gaze.

At the first visual trials this girl was then shown objects known to her by feeling, but did not recognize them, though it was established for certain that she had received a visual impression of them.

> She was thereupon told to touch the objects; with hand half-closed, she hesitantly executed an extremely awkward, aimless movement straight ahead of her. If, as generally happened, she did not light upon the object at once, she let her hand drop limply into her lap and could only

with difficulty be persuaded to try again. On encountering the object, she immediately recognized it by feeling.

Now here this movement the girl makes to grasp the presented object cannot be dismissed as a normal piece of tactual groping, if only because it is not performed as usual, or at the normal speed, but slowly and hesitantly, under conscious guidance from the visual impression. It may therefore be asserted that in this case also she possessed from the outset a conscious impression of indefinite visual depth; that she could not gauge the distance of these unknown visual objects does not prove that she did not see them as in any way separated from her. To be sure, the special contributory factor here is the lack of any awareness of space in general, due to her blindness. Having no previous acquaintance with anything spatial, her first post-operative visual impression is unable to persuade her to make any more ample gesture into visual space, though visually she registers a certain impression of depth. The idea of space is something so essentially novel that at first the patient is not really prepared to believe in the givenness of objects beyond arm's reach.

Here too, though slow at first, her increasing interest in her studies led to rapid progress. Thus despite the lack of an eye, her estimation of distances within reach became reasonably accurate after one-and-a-half months, and beyond it after two.

This case is particularly important, because with the elimination of visual impressions and the gradual fading out of memory-images, whose disappearance she had plainly not tried to postpone by the exercise of imagination or the attempted recollection of scenes in her own past, the girl seems also to have wholly lost her awareness of space. Another important feature is that, even to the one eye operated on, visual objects immediately appeared to be located by a certain visual depth. It should also be noted that the first trials were conducted on objects situated within her reach, and that in spite of this she did not reach too far in attempting to grasp them, but not far enough; a further proof that she was consciously guided by the visual impression, and not merely extending her hands to the customary tactual distance.

LATTA [60] says of his case:

The first thing he actually perceived was the face of the house-surgeon. He says that at first he did not know what it was he saw, but that when Dr Stewart [who was bending over him] asked him to look down, the sense of hearing guided his eye straight to the point whence the sound came, and then, recalling what he knew from having felt his own face, he realized that this must be a mouth, and that he must be looking at a face.

We have already commented on this passage in Part I, where it was a question of how the contribution of hearing was to be evaluated here. In the present connection the passage is significant in showing how, in this instance, the patient's whole interest was so exclusively devoted to the problem of what the object was, that the question of its whereabouts never even occurred to him. And this just shows that visual depth was simply given to his eye along with the visual object, and did not form a separate element in his perception. Only if an inquiry about distance had presented the spatial as a special topic of consideration, might he then have been in doubt, had it not been for the clues he possessed in the very circumstances of this episode, such as the loudness of the surgeon's voice and the stirring of the air that went with it.

Thus in Latta's case also we see how the impression of depth is given to the operated eye at once, and how it also brings into being an awareness of this spatial depth. No experience is needed for perception of the impression as such, save only when it is a matter of saying something about the actual depth in any given case.

AUGSTEIN'S patient is said during the first weeks of testing to have been in no way distinguishable from a blind man:

> He ran into everything, just as he did before operation, and all presented objects were identified by touch alone. All that he said himself was that everything was brighter than before, and colours much clearer.

Here, unfortunately, we are not told whether this identifying of objects by touch was effected with or without visual aid, or whether objects in general were already perceived and localized by eye. Presumably not, for his field of vision was very limited, and only enlarged gradually, from the fifth week on.

Of the tests in the fifth week we are then told:

> He was also very quick in getting to describe forms – as round or cornered – and to judge their size and distance, by sight alone, though he could only use his right eye for the purpose. Thus he could grasp accurately, for example, at an object hanging on a string, whatever the distance.

Here, therefore, conscious vision did not occur till the fifth week; previous to that, he could not yet fixate, even within the tubular field of vision objectively given to him. But as soon as conscious seeing began, the impression of visual depth seems also to have been present right away, so far as the lack of detail in the report allows one to say so.

5. General Conclusions from this Chapter

The preliminary results of our inquiry into the problem of visual space may be stated as follows: In those cases where the elements of first conscious vision could be clearly analysed by the *rapporteur* in question, it appears that the patient already perceives his first visual impression, the coloured surface still wholly undifferentiated into things, to be spatially separated from his own person. This immediate vision in depth is manifested in the patient by a spontaneous groping into visual space, occasioned by the peculiar nature of the visual impression. Moreover, this groping clearly differs from that required and made familiar in the course of his previous orientation by touch. The groping hand either follows out another route, in accordance with the objective visual direction, and is carried to a different distance from the patient's own body; or else the patients actually persist, after a fashion, in the accustomed schematism, using what they already know of sight, or from customary systematic procedures, in that they extend a groping hand away from their own eyes along the line joining the eye to the object observed, until the hand lights upon it. This type of reaction to the first visual impression may be effaced if, owing to pain in the operated eye, or dazzling due to first seeing in an inadequately shaded room, the patient is led to regard this ocular stimulus as a sensation of contact naturally occasioned by the visual object and corresponding to that felt in his touching hand; and is thereby led to declare, in accordance with his previous tactual notions, that visual objects seem to be in his eye. Alternatively – and this holds for those who work by a schema – the occasion of first seeing is accompanied by perseveration in the wholly unspatial pre-operative thinking of the blind, whereby every sense-impression is related to the subject's own body, and is to some extent felt as bound up with a part thereof; in consequence of which the visual impression is at first thought to be similarly in contact with the eye.

At all events it is a mistake to conclude that because on first seeing the patient cannot yet gauge a particular objective distance, he therefore has absolutely no impression of depth. For wherever this question, whether the patient perceives visual objects as situated at a certain distance from his eye, has been clearly distinguished from the question about his estimation of depth, the answer has also turned out to be clearly and definitely in favour of our own view. In precisely those cases where the above-mentioned hindrances have not been operative, where the

patient has not been beset by earlier modes of thought and has applied himself quite naïvely to the visual impression as such, the result has been to produce gropings into the depth of visual space, patently different from those of touch and consciously directed upon the visual impression itself.

This conclusion, as confirmed by us in a number of instances, that the patient at once localizes visual objects at a certain indefinite distance, and conducts himself accordingly, is also expressly upheld in several of our sources.

Here we may begin by referring once more to the passage from JANIN [8] already cited on p. 234:

> The sensations felt by this girl on the presentation of objects, did not in the least incline her to suppose that they touched her organ of vision, but rather that they were situated at a certain distance.

HOME, too [13], who endeavours to support Cheselden, is obliged to admit of his patient's first binocular act of vision, which he thinks particularly telling:

> The sun and other objects did not now seem to touch his eyes as before, they appeared to be at a short distance from him.

But we have already pointed out on numerous occasions that in this particular case spatial vision was also present previous to operation. DUNAN [42] says:

> Thus she saw all objects at a certain distance, though it was probably indefinable to her, because we could not get her to say anything on the subject; but *for all that she saw them projected in space.*

In GRAFÉ [49] (again under the limitations mentioned on pp. 122–125) we read:

> In general it appears, therefore, that the moment the sight of our patient was restored, he saw spatially, just as we do. If this perception in depth has first of all to be acquired, it has to be admitted that, in our patient at least, the acquisition took place so rapidly as to be indistinguishable from a primary intuition.

Various other reporters, such as Franz, Trinchinetti, Dufour, Marc-Monnier, the Getaz correspondent and others, say much the same thing in other words, when they sum up their impressions of spatial vision in their cases to the effect that, on first use of his eyes, the patient is confronted merely with a parti-coloured vertical surface, without order or distinctions of depth. They are in error only if they think to have proved by this that the patient therefore begins by seeing visual objects without

any spatial depth at all. For whatever the distance at which the newly sighted one may localize this surface, he still has in every case an impression of some sort of depth, though he cannot yet determine it. As we have seen, however, in the vast majority of cases this impresssion of depth plays a purely secondary role, for at the first moment of vision all sorts of other things have a far greater call upon his interest. In general, if the patient is attentive at this moment, he is initially far too fascinated by the coloured appearance of the whole mosaic presented to his eye, and his first question is very naturally as to the meaning of what he sees. His mind is full of this coloured confusion – generally only a very small area around what happens to be his point of fixation; whereas the distance of what he sees is not specially considered, but given automatically along with the other visual impressions.

Within this still undifferentiated coloured confusion it is obviously not yet possible to make judgements of absolute distance, since the various preconditions required for the latter are all dependent on an acquisition of experience that cannot yet be available at the first visual trial.

This experience must extend first of all to the ocular mechanism itself, and thereafter to the separation and discrimination of individual colour-patches within the given field of vision, to acquaintance with the visual appearance of individual seen objects.

Since none of all this is present at the first visual trials, it is naturally very difficult to pursue them to any sort of useful conclusion. And this is doubtless the main reason why this very ill-attested theory of Cheselden's has been able to exert so persistent and lasting an effect; the fact being that in most cases the first visual trials were insufficiently prepared, so that even in those instances where the physiological conditions were adequate, the first moments of vision were allowed to pass without result. The later and better prepared experiments then had to be brought in to fill this gap. To this it may be added that in many cases the actual significance of the findings achieved was not analysed in a sufficiently critical manner, but all too readily evaluated in accordance with Cheselden's view. It was found, for example, that the patients only learned to estimate the absolute distance of visual objects after lengthy experience; or that they could not recognize anything in pictures; or that they could not at once see the solidity of things; or were deceived on presentation of an object along with a similarly painted flat surface. And these facts were almost invariably adduced in favour of the theory that at first the patient is confronted with nothing spatial. But none of these questions has anything to do with the basic issue. If the patient has

anything like normal vision at all at first sight, he perceives visual objects, though as yet he naturally cannot tell their significance. And the question is whether, on seeing these colour-patches or already separated objects for the first time, he consciously feels them at once to be spatially remote from his own body. The problem of visual awareness of space depends only on an affirmative answer to this question. Whereas a negative answer to the other questions represents at best a further indication that, before operation, the patient is not provided by his remaining senses with anything that can be called an awareness of space, so far as this implies an awareness of spatial depth and shape.

The proof that judgement of absolute distances depends on experience may be taken along with the answering of our next question, since in their experiments the observers commonly conflate the two.

II

PERCEPTION OF DIFFERENCES IN DEPTH

The second question associated with vision in depth is whether, on first seeing, the patient's whole visual field presents a single vertical surface of the same apparent spatial depth throughout, or whether he at once perceives larger differences of depth in visual space as well. It may be observed that only a few experiments have been undertaken on this particular matter, so that here again we are dependent on inferences from other tests. In those relating directly to comparisons of depth between different objects, the attempt has been made to exclude indirect aids, such as visual size, by endeavouring to compensate the varying depth of the objects presented by corresponding variations in their size. In another type of experiment the procedure is reversed, by asking, not for the relative distance, but for the size of two objects of similar form but different sizes, set up at suitably chosen degrees of depth. Unless such tests are made very early, the question naturally arises once more, how far the patient is already advanced in his grasp of shape, and to what extent he is trying to help himself along by the use of schematic aids, for example. This was also one of our reasons, indeed, for taking the problem of visual shape first; so that we might refer back to it at any time. It also seemed advisable because we shall subsequently be attempting to follow out the development of awareness of spatial depth.

1. Binocular

RAEHLMANN I [45] made experiments of the second type. Since he was anxious to trace out the way in which experience was gradually acquired, he did his best to restrict his patient's own opportunities for this by keeping the eye bandaged for the first few weeks, except during testing. The first trial was made with a cup and a porcelain jar, ten times larger and sixteen times farther away. This was at the very outset. The nineteen-year-old patient took both objects to be the same size, and four days later he did the same at seven times the distance.

A teaspoon and a tablespoon, of the same shape and held at different distances, were taken to be the same spoon.

Conversely:

> Of two objects of equal size, the patient takes the farther one to be the smaller.

From this specialized mode of questioning as to the relative sizes of objects one cannot immediately conclude that he perceived no differences of depth at all. Since he had hitherto had virtually no conception of spatial depth, it is possible that he merely failed to notice differences of depth, since they fell outside the scope of the question. But it is also very possible, indeed probable, that the two objects, which the patient will have seen, as such, at a distance, were seen at the same visual depth, in consequence of his coupling them together for comparison, as is well known from the literature on the subject. In comparing *sizes* there is always an ordering of the seen objects in the same visual plane, the patient being guided solely by the apparent sizes of the two objects.

But when he has only *one* object to attend to, he has a clear impression of change of distance and can even grope correctly towards it, so long as the object remains within his reach, and within the centre of his visual field, i.e. within the region commanded by his physiological degree of vision. Even ten days later he had not yet succeeded in relating visual size to distance. Space, for him, is still merely the immediate area within reach of his arms. But when reaching finally fails him, he stands up and plods forward until he grasps the object.

Even these few experiments, conducted always within the rigid confines of testing sessions, where the young man could make no trials of his own, had already given him a pronounced awareness of differences in spatial depth. Yet at first this awareness plainly consisted only in realizing the different number of steps needed to grasp hold of the object. Only gradually was the change in its visual appearance on approach accepted quite vaguely as an accompanying phenomenon, then separately apprehended, brought into relation with his own walking-movements, and finally distinguished as a separate visual experience.

In scarcely any other patient has this gradual taking possession of the depth of visual space been so fully brought home, by systematic practice, as in this case of Raehlmann. Nor has any other patient been thereby roused to such independent experiments as those he conducted for his own instruction:

> According to an intelligent invalid who shared his room, the patient engaged for a time in self-observation, and practised his vision in a

> strange fashion; thus he takes off one of his boots, throws it some way off in front of him, and then attempts to gauge the distance at which it lies; he takes a few steps towards the boot and tries to grasp it; on failing to reach it, he moves on a step or two and gropes for the boot until he finally gets hold of it.

Nor did success elude him; he became quite accurate in judging distance, even with objects of which he had had no experience, such as threads. Nor was he taken in by the experiment with coins in water and fake coins on the surface. But even at this stage, after three weeks' experience of seeing, 'space', as he conceives it, ends with visual space, i.e. with the colour-patches that happen to bound his view. He does not yet have the notion that a larger object (a chair) can mask a smaller one (a dog), or that the latter can still be present even though it is not directly seen; yet another effect of his tactual experience as a blind man, for whom reality attaches only to that which is in immediate contact with his own body, or is known in terms of the spatial schema to be capable of being so brought.

In the open air he is also wildly out in his judgement of distances. Thus his ability to judge absolute degrees of depth correctly depends on the objects, whose apparent visual changes are brought into a fixed relationship with distances empirically determined and so approximately known to him. Here it is most essential that he should already possess a visual memory-image of the object in question, of a specific visual size and at the distance known to go with it.

In AHLSTRÖM'S nine-year-old girl patient [51], interest in vision again grew only with success, and so broke down her initial shyness and apathy. Here too the experiments on differences of visual depth were combined with those on differences of size.

> If I presented her with pieces of card of various sizes, putting the smallest nearer and the largest at some distance, she invariably said that the one nearest to her was the largest; she still made similar mistakes several months later, especially if the position of the cards was so altered, that one of them, although the smallest, presented a larger visual angle than the other and larger one.

This passage is of great importance, so far as its wording correctly reproduces the actual observed facts: for from this it would appear that although she was asked about size, the child spontaneously made an assertion about visual depth, and so must have had a clear impression of differences therein. Alternatively, if Ahlström merely wished to record the objective fact that the child simply pointed her finger, say,

without speaking, at the card that was actually nearest, he ought to have said 'of the one nearest' and not 'that the one nearest'. It hardly seems a likely error to have made. . . .* As to the gauging of absolute distance, we read:

> It was equally difficult for the patient to tell the distance of the objects, especially when they were somewhat remote from her; yet she was quick and correct in learning to give the location of objects in her immediate neighbourhood. . . . Three months later it was still hard for the child to determine larger distances, for she always supposed them nearer than they actually were. Yet here too, in the course of time, she had acquired greater skill than at the outset, when she could not gauge the smallest distances.

From this it would seem that distinctions of distance become immediately discernible as soon as the patient can effect a separation among the given colour-patches, without the need for determination of absolute distance to be first preceded by experience.

It is interesting, in this connection, to read what Ahlström says of his experiences with cataract patients blinded later in life, and likewise operated on by him:

> Shortly after operation the majority of cataract patients certainly commit a variety of errors in judging distance; but the girl in question made far more than an elderly cataract patient whom I operated on at about the same time and subjected to the same series of tests.

This shows that even with patients blinded later in life, who still possess visual memory images, a process of transposition is necessary owing to the loss of accommodation due to removal of the lens; and hence that accommodation is an essential factor in our impressions of depth. But this would also mean that (owing in turn to the greater clarity of the images) there is more in the way of depth-impressions given to the eye by Nature, than can be given to the operated eye of a congenitally blind patient, once accommodation has been lost.

MINER's subject [59] had been scientifically trained. His laboratory tests with her, which were not undertaken until two and a half years after the first operation, were therefore concerned, not with a gradual development, but with the status attained by the twenty-two-year-old girl in the course of this long period. In this instance, too, his details are inadequate, since he does not give absolute measurements, either for the

* There follows a sentence referring to this Swedish author's possible misconstruction of the German subjunctive. There is no way of rendering the point effectively in English, and it is therefore omitted – Tr.

balls used in the experiments, or for the range at which he made his reported measurements of the intervals at which differences of distance were no longer perceived as such (with one eye, 15 cm., with both, 6 cm.). He merely says that her perspectival vision was still relatively undeveloped; so in order to give her a clearer notion of spatial depth he made her look through the wrong end of an opera-glass.

LATTA [60] reports:

> He was able to estimate size and distance more readily than might have been anticipated, although he says that he feels that if he were out of doors by himself he would be 'wandered'.

At first he took the steps of a staircase to be so high

> that, to begin with, he raised his foot much higher than was necessary and, without meaning to do so, went up two steps at a time. Whenever he discovered his mistake he began to pay attention to the rise of each, and he has now no difficulty in estimating their height.

Latta is suggesting here that the steps appeared too close to the patient, through lack of experience; but it seems as if he actually did not see or notice the next step in front of him at all, because it was too close under him; and it was only the unaccustomed muscular sensations that he then felt in his legs, which made him realize that he had not gone upstairs quite right. But in this case again it is not stated at what period after operation this trial took place. In view of the description given, it seems that here, too, the impression of differences in depth between the individual steps in front of him was so clearly given, in fact, that it actually led him to raise his feet so high in this quite unaccustomed way.

Here also the gauging of depth is coupled with estimation of size:

> In general things seemed larger than he expected; but the great extent of space did not impress him until he had left the hospital.

This is again proof of the fact that the many square miles of space that he had actually commanded as a blind man had not been in any way spatially picturable to him; and that walking in fact means nothing more to him than the mechanically rhythmical 'movement' of his motor apparatus, which he can automatically set going for a certain time. The distance actually travelled can only be conveyed to his mind by the number of miles or by the fatigue arising on long continuance, but not as a tract of space experienced by himself.

Since the patient can only acquire a numerical knowledge of distances, but not a living idea of them, he will at first underestimate all distances

greatly, after the operation, because he simply cannot imagine that anything perceived by one of his senses can be very far away.

But it will naturally be intelligible, on the other hand, how a man like Latta's first patient, who brings such a knowledge of space with him, can also apply this knowledge to his new impressions, and so is much quicker than other patients in getting to the point of being able to grasp relationships in visual space.

UHTHOFF I [45] only made experiments of this type in the fifth week of visual testing, and this too by way of making the boy estimate the size of objects hung at varying distances:

> The experiments were continued by showing the patient similar objects of different sizes (white cards, lumps of sugar, etc.), hung one behind the other on thin black threads, and in such a way that the smaller items were quite close to his eye and the larger ones further away, so that the visual angle of the larger was at best no larger, or smaller, even, than that of the small ones. The patient is then asked which object is the smaller and which the larger; he hesitates at first, but then answers correctly; at subsequent trials also, his answers were equally correct in this respect.

Uhthoff was himself surprised at this result, and thought he had delayed too long in making these experiments, so that by this time the objects would have already been too well-known to the patient; otherwise this recognition of the varying distance of the objects would have been impossible to the boy. But since, eight weeks after commencing practice on visual objects, the boy was still clinging primarily to their colour and a few schematic features, his familiarity, at least with the cardboard shapes, cannot yet have been so very great. But that his statements may still have been a true case of perceiving differences of depth, and not of comparing two distinct absolute distances established by familiarity with the objects, is particularly evidenced by the fact that at this time the boy still had no idea at all of estimating depth. Uhthoff himself had gone to every conceivable trouble on this very point; but had made only very slow progress with him, because all spatial concepts were lacking in the boy, and could only with difficulty be established even after the operation. After three days he had attained to a certain admittedly inaccurate judgement of depth within arm's reach, but he then remained fixed at this stage for several months. Uhthoff himself does not attribute this to defective acuity of vision, but supposes that it is in general difficult for such patients to achieve any conceptual grasp whatever of remoter space; which is confirmed, indeed, by many other

authors. But in this case, the exceptionally long period spent in acquiring experience suggests that special individual peculiarities were also operative as well. And here it emerges from the report that, owing to great differences of visual acuity between the two eyes, binocular vision in general had only developed very slowly, after one image had seemingly been neglected at first, since double images could not be obtained by any means. Besides, the boy's mental development had been seriously neglected, his memory was very weak, and even after operation he remained, in general, just as passive as before, and allowed all the tests to pass him by without any real pleasure, though when he really had to do so he displayed perfectly adequate visual ability. We have also met this picture in other cases (Albertotti, Vurpas-Eggli *et al.*), where similarly strong resistances had to be overcome. Two and a half years later, on a follow-up examination, the picture had altered:

> The boy is now nine, and grasps quite promptly at objects held before him, and judges distance correctly, as soon as he uses both eyes; his vision is therefore binocular. . . . As soon as one eye was covered, uncertainty followed – the difference was extraordinarily striking. There can be no doubt that the patient now has binocular vision.

Uhthoff expressly remarks at this point,

> that in the two-and-a-half years that have passed since the operation, this boy, who was previously so dull and apathetic, has become a very lively and artful lad, whose wild pranks and frolics often disturb the neighbourhood. At all events, the restoration of his sight has had a very beneficial effect on the development of his intelligence.

Here too it seems on the whole to emerge that *judgement* of depth depends on the gaining of experience, and this in turn upon numerous emotional factors; there is a continuous mutual fertilization between outer impressions, the visual capacity, and the use made of it. Apart from the physiological power of vision, it therefore depends very largely on the *will* to see, and whether it can be aroused if it is not already present.

Now although in this case of Uhthoff's the gaining of experience proceeded exceptionally slowly, the impression of objects in visual space as located at varying depths seems here also to be given at once, as soon as the patient's vision has become capable of separate attention to individual colour-patches, as distinct from others.

2. Monocular

We have already made some allusion to cases in which the patients first have one eye available, and only later both. Whereas Uhthoff reports a

very striking difference between the two forms of seeing, Hirschberg arrived at a contrary result. It will therefore be interesting to examine the other *one-eyed* cases on this same question, whether they at once have the impression of differing visual depths, and how they proceed to gain experience about depth and distinctions of depth among different visual objects.

In WARDROP II [16] the patient

> seemed to have the greatest difficulty in finding out the distance of any object; for, when an object was held close to her eye, she would search for it by stretching her hand far beyond its position, while on other occasions she groped close to her own face for a thing far removed from her.

Six weeks later, her certainty had not yet increased.

DUFOUR [26] made no special tests for vision in depth. But the following passage is very typical, relating as it does to a period when the patient is actually beginning to acquire a notion of vision. It runs:

> I had two or three times conducted the patient to the window of the room, but he had behaved as if confronted with a medley of colours and shapes, in which he could detect no order of any kind. Apart from the light grey roof of a yellow building which lay below the house (Echallens railway station), he pointed out nothing of his own accord. Now in front of the house the view is open; beyond the garden a few houses, then a valley, beyond that again a green hillside, and finally the blue of the lake and the mountains of Savoy and the Jura. Noé seemed to see little, and could make sense of nothing. First he noticed the green of the nearby lawn; later he said to me: 'I see something blue'; on so saying, he was gazing at the lake in the distance. I explained to him that it was a huge sheet of water; he completely failed to understand this. . . . Even when he had many times looked out of the window, Noé M. could get no clear picture of the open space before him. The landscape seemed to bewilder his thoughts; he pointed out the bushes around the lawn, distinguishing their sizes, but beyond the yellow house that we had explained to him, he could really interpret none of his sensations.

He also picks out the clear-cut crest-line of the Jura, but can make nothing of the sight, even when told that it is the crest of a range of hills. Dufour adds the remark quoted on p. 37:

> The patients have difficulty in conceiving that our senses carry so far and in a sense can also perceive so far; nor can they imagine a great distance in any other way save in terms of the time one has to spend walking in order to get there.

Some seven weeks after operation, Dufour again says:

> By and large, our patient commits no gross errors in the estimation of distance when looking at an object that he has touched, and of which he therefore knows the absolute size. Thus he gauges with some accuracy the decrease in apparent size arising from the removal of the object. By contrast, all large distances (1 kilometre and upwards) are not yet accompanied by any exact notion in his mind. He sees contours and colours; but when I talk to him about a very long distance, it does not seem as though he can imagine any such thing. One almost has the impression that Noé M. is a man for whom distances become incommensurable at about a kilometre away.

Across the green expanse of garden, over the bushes, and up to the station building, there seems to have been, in this case also, an impression of different visual depths. But what makes the conscious grasp of this impression so very difficult for him, as it is when grasping large distances and in gauging of distance in general, is this confusion of all his previous concepts, which Dufour might have done even more to stress; this need to transpose everything out of the unspatial terms common to all tactual knowledge, into the spatiality of all that is known visually.

A somewhat crude experiment on recognition of visual depth-differences was made by DUNAN [42]: He stationed his assistant two yards away from the thirteen-year-old girl, and himself some two yards farther off. According to the patient, both visual images touched one another 'absolutely side by side'. When Dunan then stepped back another two yards (i.e. six yards away in all), the patient noticed by the sound of his steps, which he could not altogether silence (and doubtless by the seen movement as well), that there was a change going on in her visual field; this time she said that Dunan looked 'just a little bit' farther away than his assistant.

This unfortunately meant the end of the experiment, so far as Dunan was concerned, and he then merely sums up his general impression of her spatial vision, as already cited above.

SEYDEL [58] made no special experiments on recognition of depth-differences, and refers to it only in the passage already quoted on p. 240:

> As for the gauging of distance . . . here too, though slow at first, her increasing interest in her studies led to rapid progress. Thus despite the lack of an eye, her estimation of distances within reach became reasonably accurate after one-and-a-half months, and beyond it after two.

The case described by LEPRINCE [63] arrived at an awareness of gradually increasing distance by means of an experiment of his own. Before operation the boy had found amusement in listening to a ball

rolling, guiding himself by hearing in a particular direction, and then searching for the ball again by touch in the presumed area. When he now feels an orange in his hands, after the operation, the tactual impression at once informs him, as with von Hippel's child, of the uses to which it can be put; he thinks of this game, is full of expectation as to how this oft-practised routine will look to the eye, and so

> entered into possession of the space beyond the limits of his reach.

In this procedure, the whole of the knowledge gained by previous experience was available; he follows the rolling sound as it dies away, knows that this is a sign of increasing distance, and now can consciously relate this old schema of his to the continuously changing visual image of the rolling orange. He could thereby grasp the impression of diminishing apparent size as a visual indication of increasing distance.

But there seems to have been no subsequent practice in estimating distances, because of the boy's general inability to extend his interest in his visual capacities beyond the satisfaction of his most immediate everyday needs. The report gives no indication of how far this may have been due to lack of visual acuity. But according to Moreau there was no deficiency here.

AUGSTEIN'S case [64] may equally be reckoned among the one-eyed, because his left eye remained so weak and so severely crossed that, as tends to happen with squinters, the visual impressions from it were neglected. Here too, no individual experiment is reported, but merely the results achieved after four weeks:

> He was also very quick in getting to . . . judge size and distance, by sight alone, though he could only use his right eye for the purpose. Thus he could grasp accurately, for example, at an object hanging on a string, whatever the distance.

This statement is of value in so far as it shows that even with one eye alone, and without accommodation, a certain accuracy can be attained in the judgement of depth; and hence that our own uncertainty with one eye may well be largely because we are too pampered in our use of two. It may be wondered, though, how far this patient was not able to orientate himself about distance through other auxiliary factors that Augstein failed to detect.

HIRSCHBERG [24] made the following experiment with his seven-year-old boy on the first day of testing, having previously let him have a good look at various objects:

> I then stationed him in his previous position, with his back to the

> window, held up a pair of similar-looking knife-handles at different, though moderate distances (one or two feet from the eye) and desired him to grasp the nearest. He did not make many mistakes at this, though he did not straightway lay his hand on the object he took to be nearer, but commonly first reached beyond it.

Before this experiment the boy had not yet been able to gain any experience about apparent size. And here again the recognition of depth-difference is coupled with the gauging of absolute distance in the one experiment: the first succeeded at once, the other did not; though the error was partly due to the fact that he was not yet able to govern and guide his motor activity in response to a visual perception.

Hirschberg does not go on to follow up further progress in detail; but reaffirms, on the seventh day:

> The relative differences between two short distances were correctly estimated, but not absolute distance, since he continued to make contact with the presented object only in a roundabout way.

The coordination of visual perception and motor activity had not yet been achieved at this stage, and yet experience has already made itself strongly felt:

> The general principles of perspective began to dawn upon him. When I stood some three feet away from him in front of a chair, which was half hidden by my body, he said very decidedly that he could see that the chair was standing behind me, and seemed to perceive that the remoter object was partially obscured by the nearer one.

Thus in this case a certain finality had already been attained by the seventh day. The boy had probably noticed repeatedly, during the visual tests, how various visual objects were alternately obscured when in motion, and had learnt from this partial screening of one object by another that visual space extends beyond the colour-patches by which it is immediately bounded, and that there may be further objects lying beyond those directly in view. This screening effect has now become a method whereby he knows that the hidden object is farther away. This again represents a sort of routine-awareness, or visual schema.

Recognition of this phenomenon of partial screening presupposes, however, that the patient already has an approximate memory-image of the hidden object, as in this example of the chair. From the first tests onward, however, Hirschberg had been very actively concerned with the seeing of shape, and had sought to drill the boy mechanically in the meaning of visual images, so that this precondition may well be regarded as fulfilled in the present case.

The particular point to notice in the present connection is, however, that already on the first day of testing, and with no notion of shape, the boy correctly recognized relative differences of depth as such, by visual perception with only one eye.

Hirschberg then operated on the second eye, eight days after the first. Twenty days after the first operation, he went on to test how far the boy already had a proper command of visual space. He made him grasp at a pencil held out quickly at various short distances, compared the results achieved with both eyes, and with each eye singly, and so came to the conclusion that the boy judged distance just as accurately with one eye as with two. Summing up, he says:

> From this [the last-mentioned tests] it must at all events be concluded, that with one eye alone he could also judge with fair certainty as to the distance and situation of a nearby object of known size and form. It may also be mentioned that in using the right eye alone he did not first have to learn everything anew, as he did with the left. His visual apparatus commanded a certain tract of space, within a sphere measuring about three feet in radius from his eyes.

This also seems a very important finding, in view of the want of accommodation. For though the experiments remain wholly within the range at which accommodation can be plainly felt by the normally sighted, and is therefore of some help in determining distance (as we have just noted in Ahlström's case), the present statement shows, in fact, that we should not overestimate the influence of accommodation, and at all events should not regard it as indispensable.

Since these accurate estimates were possible only with objects of known form and size, it follows naturally that here the boy was fastening on to other indications; especially, no doubt, the varying apparent size at different distances of the object known to him. He will have had a memory-image of this, endowed in his memory with a particular visual size for a particular known distance. It also has to be considered that the boy could have had a clue, during this experiment, from the various movements of arm and hand that Hirschberg must have made in shifting the pencil to and fro (e.g. the varying inflexions of his elbow); and might possibly have used this here with success.

A quite special method of assisting himself was also devised, for example, by FRANZ'S patient [17], in order to orientate himself as to the spatial depth of an object. The occasion for it may well have been given by Franz himself, when he allowed the patient, at the first experiments, to shift his head sideways as far as was necessary to compensate

the defective eye, so that binocular vision could be simulated thereby:

> If he wished to form an estimate of the distance of objects from his own person or of two objects from each other . . . he examined the objects from different points of view by turning his head to the right and to the left.

Thus he notes the change in the angle of direction, or the degree of displacement of the visual image against the background, or when objects are standing behind one another he attempts to get a certain glimpse of them from the side. At the first experiment (a musket-ball in a vessel containing water to about the depth of one foot, and a piece of pasteboard resembling it on the surface), he was unable to perceive the difference in position; at first he thought them both on the surface, and then both at the bottom of the vessel. But this experiment can scarcely claim to have provided satisfactory test-conditions for the subject. For a normally sighted person could equally have been deceived, owing to the special effects of refraction beneath the surface of the water.

UHTHOFF'S experiments with his second patient [56] were also conducted on a monocular basis throughout the first month, but for that very reason he made no special tests for estimation of depth, probably because he thought it was hopeless from the start. He merely observes:

> Estimation of the distance of presented objects also remained very uncertain up to the conclusion of visual testing (four to five weeks), especially where rather larger distances were involved. Results are somewhat better when the object is within the patient's reach. It also makes a difference whether the object in question is dangled before him on a thin thread, or shown him by hand with arm outstretched; he was plainly rather better orientated in the latter case.

3. In Cases with Pre-Operative Visual Awareness of Space

The development of recognition of depth-differences and estimation of absolute distances is naturally far more rapid in those patients who already have a *pre-operative awareness of space*; nor can it be entirely lacking in these cases either, in virtue of the smallness and limited depth of their pre-operative visual field.

In WARE I [11], a certain estimation of absolute distance was already possible before operation, as was an accurate judgement of change of distance when the latter was diminished or increased. Ware himself was

probably right in assuming, of his highly intelligent patient, that although his pre-operative command of visual space had been very restricted, he had already acquired certain auxiliary criteria for recognition of differences in distance (fading of colours, apparent size); and that he simply applied this acquired knowledge when his visual space was enlarged after the operation, and could easily do so, because the applicability of these criteria remained unchanged, since they related only to recognition of the approach or recession of the object, and were to that extent independent of absolute distance.

The first post-operative visual experiences of this patient were acquired independently, by accident, when no doctor was present, so that Ware had to rely upon the account given by the mother. But he himself was then equally surprised at the assurance of his patient's assertions.

> [He] proved that he had some accuracy in his idea of distance, by saying that [the table] was a little further off than his hand could reach.

Ware then made no further experiments on vision in depth, however, but merely refers briefly to similar experiences with a fourteen-year-old boy operated on in London in the year 1794, of whom he has not otherwise given any more detailed report:

> Dr Hamilton and myself were much astonished by the facility with which, on the first experiment, he took hold of my hand at different distances, mentioning whether it was brought nearer to, or carried further from him.

HOME [13] tells us nothing of his two cases in this respect.

FISCHER [44] says:

> Already by the third day she was fairly well orientated as to the direction and distance of what lay within reach of her hands, without requiring to take hold of the objects for the purpose. At larger distances, certainty was still lacking, but she acquired it satisfactorily within the first week.

This statement confirms the reservation made on p. 79 about spatial depth.

In the case of RAEHLMANN II [47] it is remarked at the outset:

> The sight tests show that the patient is in full possession of spatial ideas;

and elsewhere:

> She had the idea of distance immediately after the operation; but she was not yet capable of gauging it exactly.

In summing up, Raehlmann again says:

Even vision with both eyes, though very important, is by no means an unconditional necessity for acquiring the idea of the dimension of depth. C. D. had this idea at the very first test after operation, and also learnt to gauge distances quickly and well, though her left eye contributed virtually nothing to her vision.

These statements already show that Raehlmann's experiment on differentiation of depth in this fourteen-year-old girl was obviously wrongly contrived from the start, so that it was bound to miscarry:

Three weeks after operation, she was set to look through a tube at a pencil held horizontal a short distance away from a white background, and told to report the distance of a ball falling in front of or behind the pencil. Out of thirty-two trials, she was eight times correct in telling me whether the ball dropped in front of the pencil or behind it.

The result of this experiment shows that in effect the girl could only guess. It is difficult even for a normally sighted person to make comparisons of depth, in empty space, between a horizontal line and a vertical one, of which the latter, in this case, was only projected in idea; for so long as our visual axis remains horizontal, our better perspective gives us a very much better impression of the depth of a vertical line than of a horizontal line running parallel with the axis of vision. On bending the head to one side through a right angle, so that the visual axis runs vertically, the relationship is reversed. Thus the experiment would undoubtedly have gone better if the pencil had likewise been held vertical, and so parallel to the imaginary line of fall. It apparently did not occur to her to utilize the alternate screening of ball and pencil as the one fell past the other, as a guide to which of them was in front; it may well have been useless to her at that stage, owing to the speed of the falling ball. But in this form the whole process occurred much too rapidly for the child to grasp, or for any expectation of a result capable of telling anything one way or another.

Already before operation FRANCKE'S patient [50] could give an approximately correct account of the distance of an object held before him, up to half a yard away. The report runs:

After the opacity in the refractive media had cleared up, the ability to estimate distance was fairly accurate and good from the start, and the range had increased from one half to about two yards. Special practice in this was therefore no longer necessary; nor could the distance be extended any further than two yards, owing to high-grade amblyopia.

4. Lateral Error on Groping towards the Target

In this connection it is noted in several passages, as an argument against the initially spatial character of vision, that when the patients attempt, at the first visual tests, to grasp at a fixed object, they continue for some time to *grope past it*, not only in depth, but also *to one side*. This is taken as proof that at first the patients do not even perceive visual objects in a definite spatial direction.

The authors in question have simply failed to notice here that the lack of spatial direction is already inherent in the previous condition of their patients, that all their reactions to any sort of sensory stimulus have always been merely approximate, and that however specific the blind man's impression of 'direction' may seem to him to be, he can never react to it with a precise movement. He is generally in direct contact with some known point in his 'spatial' schema, from which point outwards he is orientated as to the position of other sensory stimuli by virtue of his schema, and therefore has no surprises to fear. But where this is not so, he is perpetually on the watch for any sort of sense-impressions, which may spur him to action or give him a clue to his orientation. On the arrival of such an impression (tactile or acoustical), he sweeps his arm horizontally from side to side in the supposed direction, on the assumption that this will be the quickest way of finding a point to work from. Even a continuous auditory stimulus never gives him more than a zone of direction of a certain distinctive width, so that by simply thrusting out his hand he will only occasionally hit upon the target at once. He will not do it straight away, if only because he has no organ by which to control the movement of his arm towards the supposed objective. So to that extent the guidance of the motion of his limbs towards a visually perceived target is a completely novel task for the patient, in which he has to attend to, and keep track of, two different things at once.

It is therefore natural for the patient to pursue these same familiar groping movements towards visual impressions as well; their sweeping motions may well begin by carrying him past the objective, so that he mostly comes upon the target from the side, but he gets there very quickly without much beating about. At times, indeed, this procedure is actually quite deliberate, once the patient has discovered that in grasping at an object his hand suddenly obscures it and so removes it from sight. For at the outset of visual learning, such a screening-effect is

equivalent to a mysterious disappearance of the object itself. The moment it vanishes behind his hand, his line of fixation immediately strays away from the object in question, and he then cannot so easily find it again, since he has not yet learnt to make use of his peripheral retinal imagery. He has such images, indeed, much as the normally sighted do, though their scope is often restricted; but he is already far too engrossed upon the unknown thing in his line of view to be able to pay any heed to them. To an eye unused to shape, moreover, the outlying impressions are far too vague and indefinite for him to realize in general that such images are useful. And finally, he has so little command over his eye-muscles that he has to search with his whole head. Hence the endeavour not to lose sight of an object once fixated. And in seeking by hand, so as to grasp an object pinned down by eye, he is then most readily led to keep an eye on the hand as well, when its image already falls upon the outer part of the retina, and is therefore indistinct.

But there are also cases who begin by taking the shortest route to the goal with their hand, even though it obscures the object, and who do this through having consciously thought about the nature of the task. This behaviour derives from the mental habits of the blind, who before operation are unable to think of vision as anything but a special form of touch. When instructed to take hold of a seen object, they naturally think of first bringing the prehending organ up to the untried organ of perception, and attempting the task from there. This groping, then, is also approximate in its execution, but is guided by the knowledge that the hand is thereby bound, sooner or later, to encounter the object. It is thus a fumbling in the direction of what is seen, though the actual act of grasping is still predominantly tactual in character. But since the patient only hits on this resource by reflection, he also takes note of its success, observes after some trials that in practice he sometimes sees only his hand, and sometimes a part of the object sought, and so soon learns by experience to employ the other method as well, and to approach his hand to the object from another direction.

This fumbling to one side is important to our present line of inquiry only so far as the patients correct themselves at the time, and in most cases arrive at the target. But in this they show yet again that they realize when their hand has overshot the mark too far on one side, so that the difference of distance has become perceptibly too large.

Thus the general answer to our question is that, so far as the experiments reported in our material can be deemed reliable, they appear to show that at first sight, without experience or any idea of shape, the

patient still has a rough impression of large differences in relative depth; assuming, of course, that he has already got so far, at this stage, as to apprehend the individual colour-patches as belonging to distinct objects.

III

PERCEPTION OF SOLIDITY

1. Binocular

In very few reports is it maintained that the patient sees objects from the start as three-dimensional solids.

According to GRAFÉ [49], an upholder of nativism, his fifteen-year-old patient stated

> that from the very outset he saw objects exactly as he has also seen them since, i.e., as having depth, relief, protuberances, and in general everything that goes to make them stable and solid. His assertions on this point were perfectly definite and unshakable.

Some doubts as to the correctness of this statement are sown by Grafé himself, who could not check it, since his tests were not made until two months after operation.

RAEHLMANN'S two patients [46-7] show the difference very clearly: eight days after operation, with a visual acuity of 1/10, his nineteen-year-old first patient could not distinguish a body from a similarly painted disc of equivalent size, though in the course of five weeks he learnt to do so. Here we are told quite plainly:

> By sight alone, Johann Ruben was unable to distinguish a sphere from a disc, or a cube from a square board. Apart from accommodation, which is naturally lacking in a cataract patient, he commanded all the aids possessed by a normally-sighted person; in spite of this, and even when he had already touched the objects, he could not at first discover the solidity of sphere and cube by eye alone.

In the second case, however, Raehlmann established that the fourteen-year-old girl had a complete command of spatial ideas.

> Thus she correctly recognizes a round board of the same cross-section as the sphere. She also distinguishes accurately between a cube and a small panel of similar cross-section.

This is one of the cases of whom we have been able to show that she already had a visually acquired awareness of space before the operation

(*cf*. p. 85). She must, indeed, be reckoned as one-eyed, since the left eye remained severely amblyopic. The first case, by contrast, had both eyes available, and so, on general assumptions as to the effects of lateral displacement, must undoubtedly have had a perspective view of objects presented a short distance away; assuming that the eyes could fixate and converge, and had approximately the same acuity, so that binocular vision could be taken to occur.

We may now inquire as to the behaviour, in this respect, of the other cases to whom these conditions applied. And for this we may also refer to the majority of those already acquainted with visual space before operation, since in almost every case they could see no more than flat shadows without contours. Statements as to the degree of visual acuity achieved by the operation are available only in a few cases, however, since for the most part it simply could not be reliably determined. We are therefore partially dependent on conjecture.

Thus in SCHNABEL I [33], vision appears to have been very moderate, since eleven months later a further operation on both eyes was necessary. After the first operation Schnabel writes:

> Confusions between a sphere and a disc of similar colour and diameter were very frequent at first, and had not yet been wholly eliminated by the time the boy left the clinic, two months after operation.

After the second operation the boy immediately ran to an orange lying three yards away on the floor, and seized it without hesitation. But by this time he had already had long experience of the fact that in daily life we are largely concerned with solid objects.

SCHNABEL II [34] was confronted only with flat shapes during the tests, and so – manifestly influenced, in part, by perseveration – mistook a white ivory ball an inch in diameter for a round paper disc, and later, conversely, a painted paper disc lying on the floor for an orange. In neither case was vision employed spontaneously.

UHTHOFF I [45] made similar experiments with egg and disc, but not till two months after operation; the child took them both to be paper:

> But this time a single tactual check was sufficient, and no such confusion ever occurred again, either when both eyes were used together, or with one alone. The experiment with a white disc and a sphere had a similar result; but later the patient regularly distinguished them, though it was quite impossible to get him to say how he did so.

AHLSTRÖM'S nine-year-old girl [51] wore spectacles of +10 D; this girl also, who is described as intelligent and greatly interested in the

matter, could distinguish neither an egg from a disc of similar shape, nor a stuffed canary from a painted one;

> Three-and-a-half months later she still became unreliable in her statements as soon as all three dimensions were involved, although she could apprehend them perfectly by touch and knew exactly what the question was about.

We find the same thing in FRANCKE [50], whose patient was among the special cases having a pre-operative conception of space. Francke worked with a cube, a sphere and an egg, together with the appropriate discs:

> When first presented, not one of the three solids was recognized by sight, though the patient quickly got to know and describe them correctly. But when, at a later session, the paper shapes were shown him, to direct his attention to the geometrical figures, and were only then followed by the individual solids, he had such grave difficulty in telling the one from the other that he frequently mistook the solids for the flat pieces of paper, and eventually grew so bemused that he even became uncertain in recognizing the latter.

This patient also wore spectacles of +10 D, and was a high-grade amblyopic.

BEER [10] gives no detailed account of the degree of vision attained by his patients, but sums up his observation of the fourteen cases he operated on as follows:

> Apart from the outline, they cannot judge mathematical solids at all by eye alone; thus a sphere appears to them a circular disc, more or less illuminated at particular points. But feeling, and the direction of motion in their hands, together teach them that this body also curves away backwards, and so at length they learn to recognize its shape completely, by the rays reflected from the body to their eye. Thus so far as judgement of the form of bodies depends upon the distribution of light and shade, it presumes a comparison of ideas of bodily form derived from feeling, with those acquired from sight.

In the GETAZ case [65] we again have no details of visual acuity. It is merely stated that within a few days the eye-muscles were functioning perfectly throughout, and that the visual images were then 'as sharp and clear-cut as anyone's'. The report goes on:

> . . . for two days she could not get her sense of perspective working at all. The table in the centre of the room seemed flat against the further wall.

This girl also goes on to inspect objects all over under tactual control. The manner in which vision of solids gradually develops can be very

readily traced in FISCHER'S case [44]: progress was rapid here, for although this patient was as yet unable to distinguish shapes or objects by eye, she probably still had some visual awareness of space from memory.

On the second day of testing she received her first indication of the visual appearance of a solid object, in the shape of a large grey cat (*cf.* p. 110).

In the days following this animal becomes her plaything and test-object, whose movements continually provide her with new observations. These impressions are then still further reinforced when, on the eighth day, she plays at ball with other children, and so herself takes an active part. We are not to suppose, of course, that she perceives this change of aspect in a body separately, as a special characteristic, or consciously draws conclusions from this; but she relates the various images to one and the same object, and realizes that they belong together; and to that extent these successive images of a thing, at first quite passively experienced, but grasped as interrelated, do come to have an effect on her further behaviour towards unknown objects. When shown a bunch of flowers

> she circles round it . . . inspects it closely, at arm's length, from right and left, and finally recognizes and names it.

It might be objected that this behaviour is based on the very natural notion of transferring the pre-operative habit of feeling all over an object to the investigation of visual objects as well. But it would then be curious that this girl's behaviour should be so wholly without parallel in the other cases. It is one more indication that the fumblings aforementioned have no spatial meaning to the blind. That being so, her behaviour towards visual objects must already have arisen out of the specific circumstances in which she exercised her vision. When watching the cat moving, she makes no movement herself, but experiences thereby the various possible aspects, the changing images of one and the same material object. In playing with her companions she sees a number of individuals continually changing places with one another. She gradually takes heart and joins the game; she now herself has to move, while other children stand still, and she notes that the effect is the same. She thereby learns of the interrelatedness of visual objects to one another and to herself, and now infers the practical application of this to inanimate objects, such as the bunch of flowers, by herself circulating around it in order to take in its various aspects; her expectation being

that one of this succession of possible views will answer to or resemble a visual memory-image already retained from earlier on, and so will enable her to identify the object.

As to how the child came to perceive things as solid, and whether she was already using the separate images on each retina, Fischer himself replies as follows:

> It would be going too far to suppose that the child already had this capacity. For a girl who, three weeks after first testing, takes a hen for a cat, and cannot yet see stereoscopically even by the time of her discharge, is still too imperfect in the use of her retinal images to be able to draw conclusions from differences so slight as these. We must therefore suppose that perhaps the change in the images presented by an object, especially when moving, may have served her as a diagnostic aid in recognizing solidity. For a thing that can turn so many different faces to the beholder cannot just be flat like a piece of paper.

(The stereoscopic tests referred to by Fischer were repeatedly tried without success; the child could not make the two images coincide.)

In inclining thus to the view that the child had arrived at an intuition of solidity by purely empirical means, without the help of lateral displacement, Fischer appears to have overlooked that, of her own motion, she systematically examined objects from various distances, and undoubtedly converged when doing so, though naturally without making conscious and deliberate use of this mechanism. Nor does anyone draw conclusions from the difference in his retinal images, such as might first lead him to reckon upon the solidity of his visual impression. On the contrary, where approximate similarity of both eyes gives rise to binocular vision at all, the stereoscopic effect is likewise given, without any mental intervention on the subject's part.

In general, our material is exceedingly indefinite on this subject. But at all events, no case can be pointed to with certainty as failing to perceive solidity, once the ophthalmological conditions for it were satisfied.

2. Monocular

The contrary question, how far the *one-eyed* are able, in the absence of lateral displacement, to arrive at a visual perception of solidity, has been singularly neglected, probably because, from their purely physiological point of view, the majority of our authors thought it pointless to undertake such experiments.

And yet there seems much to suggest that lateral displacement is at

least not the only decisive factor in perceiving solidity; and that it is essentially more a matter of conscious method in perception.

The only experiments of any real significance on this point are those of FRANZ [17]. But even he was testing only from the standpoint of binocular vision, and therefore attempted in this 'to compensate the point of view of the right amaurotic eye', by allowing the patient to move his head sideways to the extent of the interocular distance. But even with this assistance, the subject merely reported seeing a square and a round disc. When the cube alone was replaced by a disc of equal size, the sphere remaining unchanged, 'he observed no difference in these objects, but regarded them both as discs'.

When the cube was placed in a somewhat oblique position alongside a plane figure drawn in the same projection, he described them both as something like 'flat quadrates'.

He was perplexed, however, when a pyramid was put before him, first with one triangular face showing, and then with an edge towards him:

> After considering and examining it for a long time, he said that this was a very extraordinary figure; it was neither a triangle, nor a quadrangle, nor a circle; he had no idea of it, and could not describe it. 'In fact,' said he, 'I must give it up.'

Thus here he seems to feel the simultaneous perception of two faces as a sort of paradox. He considers under what circumstances such a thing would be possible, but the notion of a material object does not occur to him. And this is the more notable, because they were the only things to concern him, by touch, before the operation. The course of this experiment again indicates that although, objectively speaking, a blind man certainly touches a body, he is not subjectively aware of it as an object having spatial structure. Asked by Franz to describe his sensations during these experiments, the subject himself says,

> that immediately on opening his eye he had discovered a difference in the two objects, the cube and the sphere, placed before him, and perceived that they were not drawings; but that he had not been able to form from them the idea of a square and a disc, until he perceived a sensation of what he saw in the points of his fingers, as if he really touched the objects.

Even on this account of his feelings, and despite the tactual sensations allegedly experienced, he still had absolutely no idea that he had seen objects.

When I gave the three bodies (the sphere, cube and pyramid) into his

> hand, he was much surprised that he had not recognized them as such by sight, as he was well acquainted with these solid mathematical figures by his touch.

Here again we can see that what the congenitally blind man knows as a 'body' by touch are merely tactual sequences of a particular structure, never shapes of a spatial kind. The word 'body' is associated, for the blind man, with unspatial features different from those of the sighted.

Like Fischer's patient, this subject also attempts to view the visual object from various angles; though not, like the former, to satisfy himself of its solidity, but merely as an aid to determining its distance. Thus he does not notice that he can also get other information by this sideways movement of his head; and so does not at first arrive at an impression of solidity:

> All objects appeared to him perfectly flat; thus, although he very well knew by his touch that the nose was prominent and the eyes sunk deeper in the head, he saw the human face only as a plane.

From the fact that both his young patients bumped into obstacles standing in their way, TRINCHINETTI [18] draws the unwarranted conclusion,

> that they saw, indeed, but did not know of these objects that they possessed the property of obstructing them.

In point of fact, this was obviously a case of failure to see, or inattention to peripheral retinal impressions; for if they had consciously seen the obstacles, for which they were permanently prepared from touch, they would certainly not have regarded them as phantoms of no consequence.

To complete the picture, Trinchinetti then repeated the experiment with an orange and a disc of similar size, at a distance of eighteen inches. Both objects were confused, though only once by the boy. When the disc was thereupon furnished with appropriate shading, he again confused it with the solid. Thus he had registered the shading as a qualitative mark of distinction for the visual impression of 'body'. Trinchinetti did not subsequently follow up this point in either case. In general it may be said that those patients who have only gained the sight of one eye from the operation are thereby greatly impaired in their perception of solidity, and even when actively desirous of using their sight, take much longer before they have sufficient confidence in the visual world to discard their tactual habits. If, therefore, in general, they show

a more intensive and far more frequent tendency to feel out all objects under visual control, this cannot be specially appealed to as evidence for a grasp of physical solidity, but very soon has the unintended consequence that, despite having only one eye to see with, they acquire an impression of this. This already comes about, in that the methodical all-round inspection of the object is performed (as it is pre-operatively, by touch), with a view to discovering its particular visual characteristics; these are to be recorded in memory, so that the object can gradually come to be recognized even without tactual aid. But this purpose cannot be achieved without actually twisting and turning the object on every side, so that the patient thereby gets thoroughly acquainted with the nature of solidity in visual objects. In this case also it continues to be more a knowledge that the object is solid, than a genuine perception of solidity as such. That the visual images actually received by the one-eyed are less comprehensive and concrete than those of the two-eyed, is already evident from the way our one-eyed cases show far more concern to contrive aids of every description, and thereby to make indirect use of all their visual powers.

The problem of perceiving solidity may therefore be answered from our material to the effect that, since there is no accommodation anyway, the want of lateral displacement greatly impedes and retards the perception of solidity, but does not prevent it altogether; whereas the presence of lateral displacement, on the other hand, does not regularly lead of its own accord to a grasp of solidity, if a general separation of visual objects, according to their different relative depths, has not yet entered the patient's mind. Even with lateral displacement, the impression of solidity does not occur in advance of an approximate ordering in depth.

IV

THE IMPRESSION OF DEPTH IN PICTURES

Experiments in the presentation of pictures have been carried out in some numbers, but are almost exclusively confined to the display of human figures or faces, in portraits or photographs, where the depth of the picture is very much less in evidence, as compared with its content. Such experiments yield little of importance, therefore, for the problem of how the spatial presentation of depth in pictures is perceived by the patients. For the few cases in which other types of picture were employed are likewise of little significance as regards the recognition of pictorial depth.

Thus the picture employed by BEER reproduced the natural proportions of a laden table, so that to the beholder the apparent distance of the content coincided with the plane of the picture.

AHLSTRÖM [51] remarks quite generally (and doubtless with reference to the experiment mentioned on p. 265):

> Even after binocular fixation had been established, my patient found it equally difficult to distinguish a copy from the real thing, and to judge of depth-relations in general.

Here too we are obviously concerned with life-size copies, which were not taken for copies, but for the objects themselves.

In LATTA [60] the blurred likeness on the cover of an illustrated weekly was again somewhat ill-suited to an experiment of this type. He was also shown a picture of the hospital grounds, with the hospital itself in the foreground and another building in the background. Although Latta did not undertake this experiment until six months after the operation, when the patient had already been out of hospital for a considerable period, the latter failed to recognize the house in the background as such, and

> found it difficult to understand why it should seem smaller and dimmer

than the building in the foreground. He found it difficult to grasp the distinction between the foreground and the background of a picture.

It is unfortunate that Latta did not pursue this test any further; for he could easily have found the place whence the picture of the hospital was taken, and demonstrated to his patient from there the true appearance of the building and its background, so as to draw a comparison with the impression of depth in the picture.

The young man seems to have had no impression of depth from the picture, because he had apparently localized the more distant house in the forward plane and was seeking to interpret it on the same scale as the one in the foreground, which itself had been recognized only with difficulty. Whereas it is recorded of the very first experiment that:

> Pictures were at first to him 'mere masses of confused colour',

on this latter occasion he had obviously had some experience already of changes in apparent size; though doubtless it did not extend, as yet, to remoter depths, for all that Latta assumes the visual acuity attained by the operation to have been relatively good. Here, at all events, we have an indication pointing to an important stage in the grasp of pictures; for we see that a grasp of pictorial shape on a reduced scale is possible only when the patient has first consciously apprehended the phenomenon of apparent size diminishing with increasing distance, occurring to a familiar object in real visual space. He then makes use of this knowledge in estimating depth; diminution of the visual image is equivalent to an increase in distance. Now it would also be natural for him to localize objects presented on a reduced scale in pictures at a similar visual depth; and to realize the technical possibility of reproducing pictured objects in whatever absolute proportions we please, so long as the relative proportions are preserved. And this can be further reinforced by depicting background objects also in a somewhat indistinct fashion, as had happened in the picture in question. But since the young man obviously still had no clear understanding of this experience, he was also no less ignorant of the criteria of depth, the greatly reduced apparent size and the fading of colour with increasing distance, and was therefore considerably perplexed by the picture. Most of the other patients would probably have found the same, since their eyesight simply did not carry far enough to yield this experience; the representation of depth in a pictured landscape would thus have been unintelligible to them.

For FRANZ'S virtually one-eyed patient [17], these difficulties were still further accentuated, because the impression of depth cannot have been at all so clearly brought home to him:

> Of perspective in pictures he had, of course, no idea; he could distinguish the individual objects in a painting, but could not understand the meaning of the whole picture; it appeared to him unnatural that the figure of a man represented in the front of a picture should be larger than a house or mountain in the background.

Thus in the first place, the one-eyed patient finds the pictorial illusion incomplete, because he has no acquaintance in reality with the type of binocular perspective imitated in the picture. He will therefore be the more readily inclined to take the perspectival foreshortenings and convergences in the picture to be linear markings in the picture plane. But in addition to this, the patient still entangled in blind modes of thought finds it utterly impossible, at first, to conceive of a solid object appearing larger or smaller according to its visual distance; for his previous world of touch knew only the one reality of unchanging tactual size, where 'size' has to be understood in the restricted sense applicable to the blind. And since nothing at a distance can be touched by the blind man, the only reality given him is that of what he holds in his hands, or at least can remember having so held. From touch alone he therefore knows nothing at all of the concept of 'distance', in the spatial sense of a third dimension, and so after operation he must first of all slowly accustom himself to the givenness of the visual impression of depth. He is thereby obliged to break with many old-established habits of thought, and this is not easy for him.

Nor is it even easy, in most cases, for the patient to acquire criteria of depth in the form of schematic guiding ideas, for they are hardly observable, as yet, at the limited distances initially given to him. Experiments by Martius (23) have shown, indeed, that for an object to appear the same size, up to a distance of twenty yards from the observer, its dimensions require to be enlarged, not in proportion to the visual angle, but at a relatively much smaller rate. But this means, conversely, that the apparent size of one and the same object, within the limited range at which the patient sees things clearly enough during the early post-operative period, exhibits so little variation, despite the change in the visual angle, that he is hardly aware of it. Thus, at a time when the patient's stock of imagery would already enable him to recognize pictorial content, he still has no intuitive concept of variable apparent size. His imagery relates throughout to objects seen at a short distance; he

still has no image, for example, of 'a house two miles away' as compared with 'a house in the street'.

In addition to this there is also the difficulty that pictorial representations are by no means bound to adhere to the apparent sizes given in reality. The photographer, for example, can squeeze one and the same landscape on to plates of different sizes, but on comparing the results the smaller picture is not found to create an impression of greater spatial depth.

PART IV

Consequences for the Theory of Space-Perception

Our two main problems have concerned the spatiality of tactual impressions, and the construction of visual space by congenitally blind patients after operation; and on these questions we have so far allowed the various case-reports to speak for themselves. In so doing we have exhibited the problem from as many different angles as possible, so as to come at it from every side; and have endeavoured, even in the course of analysis, to point out the connections which have led to these utterances on the part of the authors or their patients, and which first make them wholly intelligible. Hence the questions themselves have already been so thoroughly answered by a variety of concordant and mutually supporting statements, that in what follows we can confine ourselves, for the most part, to a brief summary of the results of our analyses, in order to demonstrate the extent to which the reports on the patients are capable of making a contribution to the theory of space perception.

I

THE SPATIALITY OF TACTUAL IMPRESSIONS

1. Space-Perception in the Congenitally Blind: The Negative Evidence Surveyed

Our first major question was: 'Do the tactual impressions of the blind provide them with what can properly be described as an awareness of space, in the same sense as the visual one?'

It lies in the nature of the case that, in attempting to answer this question, we should confine ourselves to those who were really blind, in the psychological sense, before operation, and so had failed to acquire a visual awareness of space. We have shown that the two groups (with or without this awareness) plainly differed in their pre- and post-operative behaviour, and some six cases have thereby been excluded from discussion. Of the remainder, which do have a bearing on the question, not one has provided evidence to support the hypothesis of a space of touch; they may be said, indeed, to have shown beyond doubt that the congenitally blind patient lacks everything that would entitle one to speak of a tactile awareness of space.

Now our patients have at times been referred to and quoted as evidence for the existence of a space of touch. But knowledge of them has been limited almost throughout to the cases of Cheselden and Wardrop II, cited by Helmholtz. The argument obviously rests on the striking contrast between the consummate ease with which presented objects are identified by touch, and their laborious recognition by sight; this being taken as sufficient proof that a spatial awareness had been present to touch, before the operation, which then had to be subsequently re-acquired by eye. The authors of our reports are largely neutral on this point; they simply record what they noticed about the tactual habits of their patients, but seldom declare themselves for or against a space of touch. A typical instance is the attitude of Raehlmann, referred to

in Steinberg (7): on reading the report one has the impression that he does not feel his own findings to be altogether consistent with a space of touch, but fails to draw conclusions from this, because he cannot imagine how there could be tactual perception without awareness of space, or because his thoughts on this subject are so rooted in old ways that it never occurs to him to draw such conclusions from his results. He must, indeed, have been even more perplexed by his second case (*cf*. p. 45); for one can really ask no more of a newly operated patient than that she should herself remark that, despite individual visual impressions, confirmed by touch, she had acquired no overall idea of a 'dog'.

On the other side, however, we have all the examples from pp. 36–70, together with the clear-cut denials of tactual space voiced in Ware (p. 37), Daviel (p. 53), Latta (p. 58) and others, and the patient's own statement in the Getaz case (p. 41).

A. NO SPATIAL DEPTH

Nor would there seem, in fact, to be a single passage in the reports capable of withstanding any degree of critical analysis, and yielding evidence for a tactile conception of space. In particular, it may be regarded as proved that his tactual perceptions give the blind man no opportunity of arriving at any adequate notion of an extended and persistent *spatial area*. This is very strikingly shown in all cases, after operation, by their extreme slowness and seeming astonishment in gaining understanding of the extendedness of objects in visual space; by the way that the extent of space intelligible to them is at first confined to the parts of a room, while location at a distance, and screening, for long remain wholly beyond them; and by the way the region of space encompassed by the intellect and presented to the senses is only gradually enlarged from one day to another. These facts should be sufficient proof that space is in no way sensorily given to the blind man, and that it is wholly and solely by operation that he is able to achieve a conception of spatial reality. In many cases even the statements of the patients themselves (such as those of Cheselden [p. 41] and Latta [p. 67]) give unambiguous evidence of their own feeling, that although they know a certain amount about the arrangement of things in space, the whole spatial vocabulary has only come to have meaning for them since they were able to see. They first have to put down mental roots, as it were, in a visual space which is already demonstrably given to them, at first sight, as having a certain quality of extension. It is only because things

had no spatial remoteness to them prior to operation, that at first they are unable to visualize distances after it (*cf.*, for example, p. 86); and it is for this reason only that some of them believe that visual objects must be in contact with their eyes.

If, subjectively speaking, the patient actually has no spatial conception of the often very large area that he traverses on foot, it follows that he can equally have nothing describable as a spatial awareness of his own objective progress through space; and hence that this motor activity must be presented to his mind in some other, non-spatial, way. Numerous passages to this effect have been cited from the reports (*cf.*, for example, pp. 37, 39), in which some of the patients clearly indicate that only since the operation has the experience of motion been brought home to them, as a change of position relative to a static spatial environment. We were able to supplement this by showing that the patient's awareness of his walking-movements is purely dynamic only (*cf.*, for example, pp. 39, 55, 109), and that the length of the road is indicated to him only by the time he spends on the move (pp. 37, 41). Even the 'straightforward' line of advance is manifested to him, not spatially, but by the uniform sensations of tension in his body (p. 39), controlled by the muscular sensations experienced during his progress (pp. 51, 57, 137).

Similar indications have been given in a number of passages (pp. 41, 42), that even on being transported through space, the passive motion is not associated by the blind with any idea of change of place.

B. NO TACTUAL SHAPE

A parallel situation is also presented in the blind man's *apprehension of shape*, whether of flat surfaces or solid bodies. The surest proof that tactual objects are not perceived spatially is again to be found in the behaviour of operated patients on their first view of shape in visual objects. They all show incontestably (pp. 114–27) that they have not the slightest familiarity with such objects from their 'tactual shape'.

This is yet further confirmed by the exceedingly slow development of shape-perception in the subsequent course of visual learning. The patient's behaviour demonstrates throughout that he is not accustomed to working up a succession of impressions into an idea of the whole. This is already apparent, in that even at the visual trials he continues for a long time to have no idea of acquiring a real conception of shape. On the contrary, he interprets the task of describing shape exactly as he did before, with tactual problems, namely, as a matter of discovering some one particular feature which will enable him to declare the 'shape'

of an object, as he understands the term. The difficulties encountered in perceiving shape are such that they cannot be satisfactorily put down to the concurrent handicaps occasioned by the still uncompleted physical development of the eye itself. And all the more so, since they were no less apparent in the cases whose powers of vision were more than usually adequate. These difficulties must therefore be looked for primarily on the psychological side of the visual process, and in our opinion they prove simply this, that our patients had acquired no idea of spatiality from tactual objects before the operation. This confirms the experimental findings already obtained by some observers before operation, and which likewise lead to the conclusion that their patients had derived no idea of space from objects known to their touch (*cf.* pp. 48 f., 52 f., 111).

This is also demonstrated in particularly unambiguous fashion by those passages (*cf.*, for example, pp. 34, 45, 62, 140) in which the patients themselves described visual objects as 'different'. The 'difference' here had no reference to the contrasts necessarily occasioned by the change of sensory impressions. It related to the feeling experienced by the patients themselves, that only after operation did the verbal concepts they had hitherto applied to the spatiality of things take on an intelligible meaning, in terms of the spatial relationships they are actually meant to describe. Diderot himself had already received from his blind man the definite impression that the congenitally blind use all spatial terms much as the uneducated make use of expressions taken from a foreign language, though with somewhat greater skill.

The wealth of confirmatory evidence leaves no further doubt that tactual objects are not apprehended in space. This again shows that the movements of the blind man's limbs can never be presented to him as spatial changes of their position in relation to his other members, his own torso, or the objects he happens to touch. And this in turn is possible only if he has likewise failed to attain to any spatial conception of his own body. This, too, has been sufficiently evidenced from a number of passages (pp. 54, 138). Some experimental confirmation of the fact emerges from the tests directed at estimating the sizes of objects, or tactual lengths, and demonstrating beyond doubt the patient's complete lack of any spatial notions in regard to his own body (pp. 47, 50–3, 56–7).

We have also had many examples indicating that the blind man experiences his own body only as a sort of dynamic centre of activity (pp. 41, 57), whose 'lines of action' are equally little conceived of as directions radiating into space (p. 38). Numerous instances have also shown us

(pp. 42–4, 46, 48–53, 63, 115, 140–2, etc.) how the blind man merely registers the qualitative impressions of his tactual objects, and attempts to incorporate the purely temporal sequence of his touchings into a schema.

C. ABANDONMENT OF TOUCH AFTER OPERATION

Further proof against the view that tactile impressions are spatially apprehended may be seen in the fact that, as soon as the patients have succeeded in orientating themselves reasonably well by eye, they *give up all the methods* whereby they had previously adapted themselves to their environment, or sought to discover in tactual objects what the sighted conceive of as shape. We have dealt with this situation in detail on p. 67 f. It is worth noting that such tactual habits often persist for a very long period (pp. 41, 69, 142), but only in those patients who have not yet effected this transfer from touch to sight; though tactual habits are often discarded quite suddenly, at a later stage (p. 67). It appears from this that there is always one particular sense that dominates over the others, and is the sole criterion whereby the patient orientates himself towards things in his environment; at first it is touch, later sight.

This change-over cannot, however, be attributed to the greater convenience of visual orientation. For the moment the transfer to vision is consciously accomplished, it suddenly becomes impossible to pursue the old tactual methods any longer (pp. 67–8). But this again can only indicate that the two sets of data, from touch and sight, are somehow irreconcilable and cannot exist side by side, or even superimposed, in the patient's mind. The incompatibility plainly does not hold between the qualitative data of the two senses, which are naturally bound to differ. For in almost every instance the patients have no difficulty at all with the purely qualitative features of visual objects (brightness and colour); in both cases it is merely a matter of registering the qualitative impressions appropriate to either sense, which continue to coexist unaltered after the operation. What cannot now be united, however, are the two methods of apprehending 'spatial' reality. They would not be thus irreconcilable if it were simply a question, in either case (tactual and visual), of registering impressions relating to the same space, but merely given differently to each sense in accordance with its special character.

But in fact the situation is ultimately this, that no real perception of space has occurred at all, before the operation, and hence that everything spatial is a complete novelty to the patient. The methods whereby the

blind have been taught to speak of what is actually spatial, have merely accomplished this object, without carrying them beyond it to any real awareness of the spatiality of the environment or the configuration of tactual things. They have failed to achieve this major object, though the teacher actually supposes them to have done so; that is why such difficulties arise, after operation, in the perception of everything spatial; and it is also why the tactile methods of apprehending 'space' are abandoned, as soon as the patient finds that the spatial is now directly given to his senses by visual impressions, and realizes that, before operation, he had no sensory acquaintance with the spatial at all. He has to abandon them, because the earlier substitutes will no longer do in the face of the full spatial reality now genuinely presented to his senses by way of the eye.

The analysis of operated cases can therefore lead only to the same conclusion that Wittmann (1), Ahlmann (2) and Gelb-Goldstein (3) have already arrived at by other means, namely that the tactual perceptions of the congenitally blind do not provide them with an apprehension of space.

Though their own experience with operated cases has long since led many of our investigators to abandon it, the belief that the tactual perceptions of the blind are spatial is still not easily shaken. The main reason for this is that we find it so difficult to free ourselves from the toils of our own visual world of ideas, and repeatedly fall into the error of judging the activities of the blind according to the degree of success that the sighted perceive in them. We do not take sufficient account of the fact that the blind man must have arrived at this success by other methods, since he bases himself on sensory impressions of a wholly different kind.

We are also only too prone to forget that all the words in the blind man's vocabulary have been taken over from the sighted, though he cannot know all that these words mean to them. Thus in order to maintain general contact with his environment, he has to fill these expressions, which to the sighted largely have some sort of visual content, with a substitute-content of a kind that he can understand in terms of his own sensory capacities. The resultant wide variations in the meaning attached to the same words by the sighted and the blind, have been clearly exhibited in many passages from our own cases.

There is yet another motive inspiring defence of the blind man's space of touch, namely that in doubting the spatiality of his impressions, we would seem to be doing him an injustice, or seeking to stamp him as a person of inferior endowments. But there can be no question of any

such thing. In attempting to understand what touch can really convey to the blind man, and then seeking to improve its performance within the framework to which it is really suited, we are taking nothing away from him. We burden him most when we recognize that touch is simply not adapted to giving the blind man an adequate awareness of spatial reality, and yet still go on exhorting him to pay heed to the spatial in his environment and in the objects known to his touch.

2. Construction of the Environment: The Positive Evidence Surveyed

To be sure, our cases have also furnished positive support for the view that, even though space is unknown to him, the blind man's opportunities from touch are still sufficient to allow him to claim his place in the world. His world is neither better nor worse than that of the sighted; it is simply different, because constituted out of different perceptual materials. Even with no idea of space, the sensations in his joints and muscles, his feelings of tension, and his impressions of touch, resistance and temperature, provide the blind man with a whole host of sensory data. He makes far more conscious use of them, and they enable him to give purposeful direction to his attitude and movements, and to govern them *ambulando*. As compared with the sighted, whose posture and movements are continuously controlled by visual impressions, a special importance undoubtedly attaches, for the blind man, to the static sense. It serves him as a sort of compass-dial; the head, in effect, is the part of the body which orientates him as to the position of his body and its members.

We need not enter in detail here into his method of doing things, since in the course of our analysis we have already made frequent allusion to the way the motor activity of the blind man is presented to his mind. We shall merely refer once more to the process of schema-formation, in order to show how, even with no knowledge of space, the blind man's environment has a firm structure of its own.

We have already given so many different examples of schema-formation (pp. 30, 35, 38, 46, 60, 63, 69, 124, etc.), that the idea will be readily understood. The blind man's schema gets its special structure from the property peculiar to all his sensory impressions. Nothing is given to him simultaneously, either by touch or the other senses; everything is resolved into successions. From a single tactual impression he can learn nothing at all. He has to have a multiplicity of impressions, and is

obliged to create this multiplicity for himself. He is therefore in need of a continual variety of impressions and has a strong tendency to activity. For only the variety provided by a temporally ordered sequence of experiences can furnish him with knowledge. Thus when no external happenings occur to orientate him, he has the urge to take action himself in order to maintain connection with his environment. He must hear noises, or hold something in his hand. The tranquil and unfathomable is intolerable to him. The moment he ceases to receive a series of impressions, and cannot create any for himself, he dwindles into a cipher. He consciously seeks to pick up every impression he can get hold of, and to analyse its meaning, so that he can then incorporate it as an item into the current overall schema. So far as impressions do not cohere, he must separate and order them, discarding one as irrelevant, seeking out another to fill in a gap, and relating everything to the impressions that have gone before. Time alone enables him to arrive at a general qualitative judgement about a route or an object, because it permits him to discover how the separate impressions hang together as past, present and future.

Since nothing is given simultaneously to his senses as spatial, it must be mentally strung together in time, which does duty for the spatiality he lacks. A spatial line must be replaced by a temporal sequence, and for this he needs an acute sense of time, so as to grasp the relatedness of impressions as belonging together.

The purely temporal schema of the congenitally blind man is therefore based on succession, change and order among perceptions of a primarily tactual or auditory kind. The schema provides him with a temporal plan of the various impressions, in his mind. The objective status of the impressions which successively enter the schema, naturally varies in each case; but the schema itself is always and everywhere serial in form. It is also invariably an ordering of sensory data, and not a conceptual affair.

The aim of the schema is to simplify the process of apprehension by laying hold of its structure, in which sensory data are stripped of their superfluous appendages, and only the essentials remain.

The effort of concentration required for this is basically the same, whether the purpose of the schema is to map out a route, a room, or even a particular tactual object. We found a typical example of a route-schema in the case of Wardrop I (*cf.* p. 70). The subject sets out from a perfectly definite central point, resembling the centre of a spider's web, whence he gains acquaintance with the routes that matter to him, up to

an outer periphery that can be more or less gradually extended. Wherever he may be, he always remains mentally in conscious relation to his fixed starting-point. Every route has its own schema, whose structure is purely temporal. Throughout the journey he moves from one expectation to another, awaiting, sooner or later, a new experience to fulfil or confirm, or even to confute, the various mental patterns that follow one another according to a definite temporal plan. It is like the unrolling of a fixed programme, where in his own mind he is always a few jumps ahead. Every sense-impression belonging to this programme is a sort of halting-place, having its own particular predecessor and successor. He has an exact knowledge of the temporal sequence in which the various sense-impressions must follow one another, since he has often analysed it with care and constantly endeavoured to complete it. His whole attitude is concentrated on the direction from which he expects to get the impressions that matter under his present circumstances. Thus he always has a known schema in mind, which progressively unfolds in accordance with his sensory experiences. There is nothing spatially experienced in this; it is merely a temporal sequence of qualitative impressions.

Once the provisional terminus of the sequence is reached, he either turns back or attempts to extend it by the addition of new stages, which are analysed as usual and appended, in memory, to the old schema. He has no spatial idea of the length of the route, but apart from time he also has the number of differing impressions involved and the degree of his own fatigue. *Thus the schema arises from this knowledge of how impressions are related in time*, as registered in his mind by frequent repetition. It is an awareness of the mutual relationship of perceptions separately received in time.

He then seeks to relate a number of such routes, all starting from the same point, by means of 'lateral' 'cross'-ties, and so to create a network of relations, to encompass and knit together the parts of the region commanded in this way.

The laborious build-up of such a schema is sufficient to explain why it takes in a considerable area only in a few cases (Nunneley, Latta, Wardrop I); and it can definitely be stated that the extent of this area is directly proportional to the mental energy of the personality behind it.

When exploring a room, the blind man proceeds in the same fashion, by successively investigating all the possible relationships therein, fitting them together and imprinting them on his memory. The number

of such possible relationships is not large, being basically confined to the walls and the various diagonals radiating from the door. The room again has no schema of surfaces, successively grasped in space, but a network of superimposed schemata. The blind man's certainty of movement in a carefully explored area of this sort is due to increasing automatization, whereby it no longer matters to him at what starting-point in the area he launches out on his schema; at every point in the room he has the whole network of relations in mind.

The replacement of spatial lines by temporal sequences also holds good for the touching of things (*cf.*, for example, p. 92). Thus he equally has no way of arriving at an awareness of shape, for in exploring an object by touch and registering the multitude of impressions so obtained, he has a clear consciousness of succession. He certainly retains the earlier items in memory, so as to relate them together in his mind with the later ones; but it is not like a sighted person, looking at a whole wall there before him and being able to picture it long afterwards as a thing simultaneously given. This imaginative retention of a completed whole is not possible with tactual impressions. The individual parts disappear. The blind man can grasp only the succession and relation, but cannot later reproduce the completed whole, as the sighted do. He has no absolute, spatially conceived measurements of tactual objects in his mind, but only the proportions of time that he needs to feel out the contours of the separate parts. Everything else that he perceives in tactual objects is of a purely qualitative kind.

Whereas the sighted person can simultaneously and immediately perceive every change in his environment by merely looking at it, so long as he has an idea of the previous state of affairs, the blind man must attempt to secure his schema against change by the use of control impressions. He must always be trying to control his schemata on the strength of such changes, and to enhance their fixity by the insertion of new impressions. The build-up of his material world is therefore never-ending, nor does it ever acquire the completeness and constancy which the sighted person always preserves in his visual picture of the world, whatever the changes in its content. Thus every change is associated, for the blind man, with a redeployment, a reorientation of the constituents of his schema. From this it will be evident that the region he commands is a very inflexible affair, with only very small capacities for change, against which he struggles as best he can. Our material has provided numerous examples of this (pp. 88, 161). This fixity of all schematic structures also bears witness to the fact that even

when individual perceptual processes are highly automatized, no conception of space results, even in the long run. Even years of practice do not make the schema any more spatial, it is merely more fluently handled. The blind man can certainly omit a few stages here and there, but for that very reason his sensory experience does not alter, and the progressive unfolding of a temporal schema persists, in principle, throughout.

In constructing and safeguarding his schemata, the blind man is largely dependent on contact with the sighted, for only through them is he first made aware of the existence of many things that could never otherwise impinge on him. Of most objects he has nothing more than a schema of this type. It is therefore the real framework of his whole conscious life. Different as their sensory structures are, it is the one link between the things of the sighted and those of the blind; it is this which allows for communication between them.

It will be seen that, take it as we will, the answer to the problem of tactual space is always in the negative. All attempts to credit the blind man with a conception of space are basically attempts to treat him as a sighted person who cannot see. But the lack of his most important faculty creates such fundamental changes in the whole structure of his conscious life that they cannot be compensated by any alternative method. It is by operation alone that the congenitally blind can achieve an awareness of space.

The results of our inquiry as to the spatiality of tactual impressions can be summed up in the following propositions:

(1) The congenitally blind man has no *a priori* awareness of space.
(2) He does not acquire it either from sensations of localization on his skin, or from the kinaesthetic sensations accompanying the movement of his limbs, or from the concomitant muscular sensations.
(3) Guided by his constant communication with the sighted, the blind man himself builds up his environment progressively in time, as a network of relationships, whose construction and stability require a perpetual and concentrated exercise of interpretative thought. He is aware of himself in this as a dynamic centre of action.
(4) By this means he creates schemata of things and verbal concepts, which partly replace the deficiency of his perceptions.
(5) These temporal schemata are the product of his attention to the

relation of events in time; they have nothing spatial about them.

(6) Thanks to these mental exertions, the blind man can get to know about the 'spatial' relations in his environment and in tactual objects. His 'space' concepts are therefore intellectual achievements only, without any sensory basis; they cannot be more than a surrogate for the spatial awareness he lacks.

(7) The logical and interpretative ordering of things is accomplished by touch, with the aid of the intellect, and so cannot be compared with the normal ordering of things in visual space. There is therefore no psychological warrant for the acceptance of a 'tactual space'.

II

CONSEQUENCES FOR THE VISUAL PERCEPTION OF SPACE

We may now endeavour to answer our second main question, as to the effect of the observations gathered from our numerous patients on the theory of visual space perception. It seems desirable here to set out our account in such a way as to give effect to the variety of practical experience encountered by the doctors, and at the same time to provide guidance for future cases, which may make it possible, for example, to choose the right moment for the first visual tests and to make proper preparation for them. Perhaps the best way of achieving this subsidiary object will be to sum up the wealth of observation and experience recorded in the reports in the form of a paradigm case, uniting, on the one hand, the practical experience gained, and allowing us, on the other, to infer from it the general conditions of normal spatial vision. We then get the following overall picture:

The first effect of the operation is merely to allow a greater admission of light to the retina. It falls upon the retina, but this does not imply that the patient is yet able to see. The increase of light is initially manifested in a strong sensation of dazzling, to be attributed, not only to the lack of a lens, but also to the long-standing and almost total inactivity of the optic nerve. But since, in most cases, the latter is simply more or less weakened in functional capacity, the dazzling normally remits after a time. It has also been suggested on occasion that the optic thalamus or visual centre in the occipital lobe are still in an incipient stage of development; and this has been taken to account for the severe amblyopia which in some cases (Vurpas-Eggli, Albertotti, Moreau) resembled a state of cortical blindness, differing from that of psychic blindness – present to some extent in all cases – in that the patients in question not only could not understand their visual impressions, but could scarcely even receive any.

Though their significance cannot be determined with certainty, an

interesting special position in this respect is occupied by UHTHOFF'S cases of temporary amaurosis following spasm of the eyelid. In the cases of three young children of two and a half to three and a half it was found that a mere three to six months' closure of the eyelids was sufficient to leave behind, when they were opened, a condition which seems to have been more than psychic blindness and really bore a greater resemblance to a relatively quick-healing cortical blindness. Uhthoff himself writes:

> All things considered, I fancy that even today the most apposite account of the nature of the phenomenon is that given by Leber, namely that the defect is purely cerebral in character; that these young children have, as it were, forgotten how to see; and that at an age when, owing to their youth, the whole psycho-physical mechanism is still so little established, the deliberate exclusion – the suppression, almost – of visual sensation plays an important part in their sensory life.

Compared with these defects of the internal apparatus, the want of the lens does not amount to much. Experiments with cataract patients blinded in later life have shown that, in short-range vision, the impairment caused by diffusion circles is not such as to present any serious obstacle to the recognition of visual objects. And since, in any case, visual acuity is bound to improve continuously at first, from its initial minimum, as the retina itself gradually attains its full functional capacity, the lack of the lens is of even less importance. After some weeks or months the retina thereby reaches a certain optimum condition, which can then be still further corrected by the use of cataract spectacles.

Since, owing to the limited input of light before operation, the peripheral areas of the retina are generally even further atrophied than the *fovea centralis*, the patient's visual field is accordingly more or less restricted at first, and only attains its normal scope in a similarly gradual fashion.

And lastly, the muscles of the eye are in a persistent state of contrary spasm, which prevents all voluntary movement of the eye for a considerable time.

But the effects of all these impediments are largely alleviated if the patient's first visual tests are delayed, not merely to the time that inflammation has disappeared, but until he has gradually been accustomed to the light. He should, of course, be given no opportunity in the meantime to indulge in visual experiences on his own account. In several of our cases the first visual tests were thereby crowned with success, so that even at this stage a genuine act of vision took place.

1. The Perception of Spatial Depth

If all these factors are attended to, the first visual experiment normally takes the following course: Once the patient has overcome his post-operative intolerance to light, and his eyes are opened to the world of colours, he immediately finds that, in whatever direction he happens to be looking, he is confronted with a visual space, the depth and breadth of which are severely restricted in comparison with that of the normally sighted.

The depth of this visual space is bounded by the nearest coloured surfaces, in most cases the furniture, curtains or walls of the sickroom. These patches of colour still appear blurred and hardly stand out from one another.

He sees them all at a certain distance from him. Things have a certain persistence at this distance. There is a particular area in the middle which he consciously seeks to apprehend as his first visual object. Nothing is noticed on the periphery as yet; his subjective visual space is thus considerably smaller than the visual field objectively available to him in virtue of the existing state of his retina. Apart from this limited visual space, the patient still has no awareness of the existence of anything beyond or to either side.

It is very difficult for him to gain access to the adjoining regions known to the normally sighted, because of his inability to put a voluntary stop to the spasm in both eyes. His eyes continue to jerk this way and that around the central point he is looking at, and he cannot tear them away from this. The visual area first experienced therefore seems unstable and difficult to grasp. The neighbouring areas can be apprehended only by turning the whole head, and this movement is likewise hesitant and jerky. Thus the separate areas successively encountered still have no relation to one another, since they fail to present a continuous sequence. He has not yet seen or come across anything beside or behind him, cannot yet remember anything, and so still has no inkling of the existence of space.

He has no awareness of what goes on in his eye when seeing (stimulation of the retina, etc.). The first statements almost invariably relate to brightness, which is often felt as something occurring in the eye and consequently localized there. Colours, too, are often described merely as brightness at first, though they are also distinguished from one another right away in accordance with their hue.

In this initial stage, vision is a purely sensory awareness of colour-impressions, simultaneously presented at right-angles to the line of vision, and still devoid of shape. The subject cannot say anything about them, nor can he initiate motor reactions towards them. He merely finds them located somehow and somewhere at an indeterminate distance in space, and does not initially take them for things at all.

Primary visual space therefore has only one thing really certain about it, and that is that the spatial is already given in sensation. Our cases might well be said to exhibit a sort of 'form of intuition' (though not in the Kantian sense), since even at this sensory stage the spatial is concomitantly presented, both in visual depth and in the visual images (along and across the line of vision). It is given, not as an independent item separable from the visual content, but as a visual modality which, so to speak, accompanies our seeing. There are not two separate visual contents, the object *plus* spatiality (distance and surface extension), but only *one*, the object *at* a distance and extended.

This condition is of great epistemological importance, since it provides a supreme example of the fact that impressions objectively given to the mind may be of no application. The patient feels visual impressions to be something alien, intruding on his mind without action on his own part. As real mental occurrences they are given involuntarily, as it were, but are very manifest for all that. Up to a certain point he receives all impressions due to visual stimulation in the portion of visual space accessible to him, but by their mere givenness they do nothing whatever to assist his understanding (*cf.* p. 134). It follows from this that visual space is not simply a function of the retina; the same conditions of stimulation are not paralleled by similar experiences.

The duration of this state depends, on the one hand, on the speed of subsequent physiological development (under favourable conditions, a truly conscious act of vision already occurs at the first attempt). But in most cases, on the other hand, more enduring difficulties arise from the mental crisis already described. At this point encouragement and systematic guidance from the doctor or psychologist must come into play; coercion may even be necessary, if the patient's own intellectual impulses do not suffice. He must be brought, under all circumstances, to the point where he grasps the principle of vision; after that, the will to see, and the realization that success is possible, normally awaken of their own accord. Having got so far, he also has the necessary urge to use his own initiative in hastening the development of his newly acquired sense.

Amid the initial chaos of blurred and vibrating colours, the patient is at first unable to make out anything definite at all. Since the wanderings of his gaze are largely out of his control, he cannot hold on to any impression; his wavering lines of sight do not allow him to pick out anything from the visual field; and when the object is shifted, or he moves forward, there is even less question of following one of the given colour-patches by eye. Owing to this helplessness, and despite the oscillatory movements, there is something fixed about his stare. Since, moreover, he has not yet learned to conjoin images that are spatially and temporally separated, the result is that external movements are presented to his stony gaze as a change in varying degrees of brightness, and not as motion at all. It also happens, on the other hand, that the rolling of his own eyeballs leads him to notice the occurrence of a movement, and that he then mistakenly describes an object as moving when it is not in fact doing so.

In general, however, it is eventually a movement, a change in visual space, which, even at the first successful trial, provokes him to follow it reflexively by eye, and so inaugurates the first conscious act of vision. This apprehension of movement is normally the first conscious visual perception. The patient thereby gets some first vague indication that he can vary the position of his eyes; an awareness which may thereupon lead him on occasion to test this possibility for himself. By the first, half-unintended perception of a change in configuration among the colours in his visual space, these colour-patches first take on an objective meaning to his mind. He now endeavours to pick out one colour from the remainder, and to fix his eyes upon it. By this effort to fasten his gaze upon a visual impression, he has himself taken the first step towards the gradual calming of his eye-movements, and hence to the disappearance of nystagmus.

Even at this stage, which may be described with some justice as the beginning of conscious visual learning, he still has no true experience. In spite of this, he shows already in his first conscious acts of vision – if not always by words, at least by his whole behaviour – that all the colour-patches in his visual space are seen from the start at a distance; even though the actual distance is still unknown to him. He does not experience colours as if they first proceeded from his eye. The depth of visual space is therefore not an illusion, or a conclusion first drawn from experience, but is something given directly along with colour. Thus it is neither a ready-made possession inherited at birth, in the nativist sense, nor an empirically derived concept of the type proclaimed by empiricism,

but a 'form of intuition'. But since, until the operation, the patient has only had vague, schematic concepts of everything spatial, with nothing intuitive about them, he still has difficulty in explaining how he sees whatever lies before him in his visual space. Even when he gropes towards remoter visual objects, this does not disprove the primary spatiality of his vision, but merely indicates a defective estimation of distance. Before the operation, the world of immediate contact was virtually the only thing real to him; now that visual impressions are beginning to take on reality, he also wishes to lay hold on them. So far as this happens at all, it is doubtless a matter of pure perseveration in habits of touch.

For the newly as for the normally sighted, visual space comes to an end at its coloured boundary, wherever the eye strikes a coloured surface. Now the normally sighted person has learnt from experience that beyond his currently presented visual space there is a further objective and known space, which he can also picture from memory. To the patient, however, the world is initially confined within this first colour-boundary; and when his pre-operative knowledge reminds him, as it often does very quickly, that there must be further spaces beyond this initial visual one, the idea of being able to move on out through the colours remains inconceivable to him.

Variations of apparent size are equally unintelligible. He cannot grasp such differences, because during his blindness he could only deal with tactual objects by direct contact, so that they have always presented the same 'sizes' to him; before operation he had no idea of 'going away from' a thing. He therefore finds it surprising that the same object can be now large and now small. This factor is not normally very noticeable at first, however, owing to the limited range of vision. In fact the patient's attention almost always has to be drawn to it, as a criterion for judging the degree of depth.

To sum up, we may say that, apart from colour, the things that are fundamentally new to the patient when he first consciously sees are: (*a*) that for the first time he is sensorily aware of a simultaneously given manifold of coexisting objects; (*b*) that this manifold appears to him at a certain distance, without his being in direct contact with it; and (*c*) that the manifold so situated displays a certain constancy, even when his eyes stray away from it for a time.

He can only have a visual space *in front* of him, and can change it only by altering the direction of his gaze. The normally sighted person is conscious of the unseen region at present lying behind him as a repro-

duction of previously seen images; or, supposing him in a particular case to be not yet acquainted with the space at his back, he still has a schematic awareness of this. The patient, on the other hand, is initially confronted only with his present visual space, as a sensory datum, unconnected with any earlier or later one. He does not know as yet that there can also be something behind him, and no space exists for him there. Even within the same visual space, he is not yet able to link the changes in the picture into causal relation with one another. He experiences them quite passively, without relating or connecting them, rather like the changing images in a kaleidoscope. His whole vision is still predominantly passive and inert.

At one of the early trials, after he has already made conscious exercise of his vision (in perceiving a movement, for example), he then slowly and hesitantly alters his own position with his eyes open, for instance by walking across the room. Even with head held rigid and looking straight forward, and even within the narrow area encompassed by his existing field of vision, he thereupon finds his visual space in process of continuous alteration. The quality of the colours remains the same, but their arrangement somehow alters in a slow, continuous sequence of change. Since his knowledge of the situation informs him, as he walks, that he is still in the same room, he is thereby led to apply this knowledge to the variations in his experience; in other words, to perceive these continuously shifting spaces to be interconnected, and hence to relate them to one and the same objective space.

Soon afterwards he generally bumps into one of these colour-patches and observes them to be substantial, since they resist him as tactual objects do. In walking about it also strikes him – or can if he pays attention – that he is continually passing in between the colours he sees, that he can go past a visual object, that a part of it then steadily disappears from view; and that in spite of this, however he twists and turns – whether entering the room from the door, for example, or returning back to it – he always has a visual space in front of him. Thus he gradually comes to realize that there is also a space behind him, which he does not see; and the separate visual spaces gradually coalesce into a comprehensive whole. Initially, at least, his attitude here is wholly receptive and he takes no conscious action beyond noticing the course of the changes. In this process we therefore have a sort of synthetic sensory awareness, a constantly self-dissolving, self-renewing and self-completing visual space.

On becoming aware of this process, the patient comes for the first

time to conceive of space, not merely as a subjective sensory experience, but also as having an objective significance, mediated by the senses. The space in which he has had this experience provides him with a first preliminary notion of objective space (which is not merely based, as before, on a constructed schema); and he then goes on to enlarge it, in stages, to an ever-increasing extent.

The amblyopic eye may enable him to recognize individual colour-patches with some distinctness, but so long as they are not yet sharply separated, and still lack substantiality, the patient generally fails, at first, to perceive distinctions of depth. The different visual planes are virtually all located, rather, at an intermediate depth from his eye.

As a rule, however, this levelling-out of all planes of depth very quickly undergoes a change, as soon as colours have come to be identified with things. The patient is thereby led to single out individual objects for notice, and this seems to lead at once to a conscious awareness of differences in depth; especially (as some cases show) once there is a partial recognition of the fact that one object can conceal another.

2. Development of the Perception of Shape

To the normally sighted adult, virtually everything seen has a certain objective meaning; a significance divorced from the merely visual or coloured, and part of his knowledge. There are no longer any visual images, as it were, that are wholly meaningless to him; even the pure blue of the sky, which might be a sheerly visual object, is endowed with a (transcendent) meaning. At best one might point, with many people at least, to the rainbow or the starry sky, as purely visual objects, in so far as they are given to the beholder as pure phenomena, without knowledge of their significance. For all that, the pure visual image is precisely that which remains constant in objects, whereas knowledge of their significance varies widely, according to the level of acquired knowledge, while the concept of the object in its 'objective significance' may alter according to the state of scientific theory.

When I say 'I see a window', these words are a false account of what I literally see. For 'window' is not a visual term but a conceptual one. I see, not a 'window', but something coloured, whose specific quality I know to have the meaning 'window'. Or when I say 'I see a man', this will not do at all, for in a purely visual sense I see only a coloured image, of his front view, for example. But the colour in itself is a phenomenon that has no back to it (sky, rainbow). I *know*, however,

that the man also has a back, and credit the coloured view of him from the front with the significance of the whole. Even the man we see is a pure colour-phenomenon, though we endow this with a vast amount of conceptual content.

Now all that the patient has of this is, on the one hand, a complex visual image of this (sensory) type and on the other a quantity of (intellectual) verbal concepts without imagery. He cannot bring the two together. As already mentioned, the constituents of his visual images only take on a certain reality as objects, when he is led, by perceiving a change in visual space, or by contact with a seen object, to concern himself with the interpretation of these impressions. In certain cases the procedure may also be purely inductive, as when, knowing that his earlier tactual objects are coloured, he concludes that the colour must serve to represent these objects.

This first step towards conferring objectivity on the pure visual image is in most cases very quickly taken (and only in a few is it virtually unattempted). As has been shown by many of our citations (*cf*. p. 107 f.), the patient then immediately sees visual objects as different, even in the absence of tactual control. This shows that so far as physiological receptivity is concerned the patient 'must perceive from the very beginning (and with more or less precision) exactly the same thing as we do; he perceives what we perceive, and as we perceive it, only not so well' (Janet).

At this moment, therefore, when the constituents of his image have acquired a certain objective meaning and importance to him, the patient's visual field contains nothing beyond a set of perfectly genuine visual objects, which are still devoid of any significance. But then even at the first tests he notices that these visual impressions awaken no familiar ideas in him, and that he cannot recognize the objects in question (*cf*. pp. 107–27). At this point the real problem of shape has become acute for him.

The steps leading to the acquisition of shape, as exhibited in numerous cases, have been detailed in Part II, so that only a few brief indications are requisite here.

It is characteristic of the patient that, in learning to see, he takes a long time before turning his attention to the contours of visual objects, even when he has long since recognized the nature of the task. There can be no doubt that this is not due solely to difficulties of fixation, but is largely because it is the purely qualitative, and primarily colour, which makes the greatest impression on his newly awakened sense, and must

therefore form the most enduring concern of his thoughts and fancies. We have likewise had a great deal of evidence for this (*cf.* pp. 108, 132, 148 f., 152). All the cases recognize colours at once as stationed at a distance, can immediately tell them apart, and very soon get to know their names out of genuine interest. For a long time colour alone determines judgement, and the contours receive not the slightest attention. The same form in another colour is not recognized as the same object.

Even when the patient perceives that these colour-distinctions do not enable him to identify objects, he still does not turn to shape as such, but invokes the aid of other distinguishing features that are easier to grasp. These we have identified as all the data he already knows through his other senses (*cf.* p. 139), and which have previously helped him to construct his schema of objects. Then again, at the tests, he often shuns the labour of diagnosing shape when compelled to say something each time about the form of the objects presented. Only under pressure of this sort can he be brought to concern himself with the outline of what he sees.

Even when he sets about shape in earnest, and is no longer greatly troubled by difficulties of fixation, it is evident that shape as such has no discernible influence on the perceptual judgements that result. It is therefore an error to suppose – and this applies quite generally – that the whole architecture of a shape is given to the beholder at a glance. Every finished idea of shape is preceded by a process of apprehension occurring in time. This was undoubtedly so with all our patients, and particularly easy to establish, since in their case a process that takes us only a fraction of a second could often be seen prolonged for several minutes. Nor was this solely due to the patient's defective control of his eye-muscles, and his consequent need to hold the eyes straight and steady and to traverse the outline with the whole head, instead of keeping it fixed and using the eyeballs as we do. The process is prolonged, rather, because the patient is still unable to use the peripheral images on his retina, and so really has to exercise care in bringing every part of the outline in succession into the very small area where he sees most clearly.

It would be wrong, however, to find warrant in these conditions for speaking of an abnormal, deviant form of shape-perception, occasioned only by such factors as the abnormally short range of vision. For even when these difficulties are eliminated, we still find the same halting method in use, so long as there are still no images of the whole.

Since all shapes are equally novel to the patient, memory-images are

lacking for a long time, and he still has no store of finished structures. The most likely source of aid is the tactually constructed schema of the object, and there is, indeed, no lack of attempts to apply this knowledge of relations to the visual sphere.

It is characteristic of all the early tests that the outline has to be traversed by eye not once, but many times, before it is possible to venture an opinion. These experiments do not give rise, as yet, to anything describable as an awareness of shape; for by the time the progress of the task is completed, the early impressions have long since faded from the mind. The patient still cannot relate the successive partial impressions of shape together and unite them into a complete picture. A considerable number of repetitions are generally needed to produce an idea of the whole. And it takes even longer before visual memory has so far developed as to preserve such an idea for a longer period, so that it is available when the object reappears, or for comparison with other objects of the same kind. Nor can it be said of any case that the patient derived any help from the form of the incoming stimulus, such as the 'optimum *Gestalt*' of Wertheimer (21) or Köhler's 'dynamical order' (22).

For this very reason, the patient scanning the outline by eye continues for a long time to keep a special lookout for some striking feature which he can retain more easily, and the mere presence of which may enable him to identify objects in this token fashion.

This endeavour to register objects mechanically with the aid of visual schemata is to be found in virtually all the cases that have been described in some detail. It is partly attributable to perseveration in tactual habits, but partly also to the burdensomeness of the task of having to recognize visual objects.

We have already outlined (*cf.* p. 285) the build-up of the schema and the purpose it fulfils for the patient, and have also described the various forms of schema involved in visual learning (p. 152 f.). In all the patient's schematic constructions we repeatedly discern the aim of abbreviating or facilitating the process of recognition. The significance of the schema in all man's conscious life has never yet received scientific acknowledgement. For us sighted persons, the schema is a sort of residue of one or more acts of perception, which forms in us almost without effort on our own part. Possession of the schema is a sign, for us, that we have grasped the architecture of an object, namely the spatial or temporal relationship of its parts. Thus it represents an essential prelude to concept-formation, since in addition to all the other cognitive constituents which go to make

up a concept, it must above all include a knowledge of structure. There is scarcely any sensory imagery remaining in the schema. All the imagery gained from perception may, indeed, be so much in the background that in speaking of an object we no longer have any pictorial imagery of it in mind, but merely the concept, and a relic of the imagery in the shape of the schema.

The patient, on the other hand, needs the schema as a bridge to the understanding of visual objects, and as an aid to the speedier recognition of what he sees. The repeated tracing-out of a lengthy outline with the whole head (which is still more awkward, since owing to the weakness of vision it has to be done at close range) is time-consuming and laborious, and does not always yield results, since the patient's memory is still incapable of retaining all his impressions and combining them into an image of the whole.

In this procedure, however, the visual form must still be consciously traversed by eye; and frequent repetition very soon leads the patient to acquire an image of the whole and so gradually to obtain a genuine visual awareness of shape.

A genuine total image naturally occurs most readily with smaller objects, that the patient can more or less take in immediately at a glance. In the apprehension of small visual images of this kind a phenomenon is sometimes observable, which would probably have been much more frequently noticed if the authors in question had known anything about it beforehand, namely the conjoint perception of two colours in the relation of figure and ground. Thus in one instance the bright reflection on a silver spoon, and in another the moon, are taken to be 'holes'. In the GETAZ case [65], we read:

> A black coat on the floor looks like the mouth of a well, a cloud of smoke from a chimney is a great crack in the bright sky and the spots on poor 'Muffy' [her dog] were alarming holes in him.

These instances could be paralleled from the perceptual habits of children, and also adults (as soon as they are aware of it), as well as in numerous turns of speech; but this would take us too far afield. The fact is important to us here only in showing once more that a given stimulus does not generate a single unvarying image in the mind, by purely mechanical transmission through the physiological apparatus of vision; and that one may actually see a variety of things, though the stimulus remains the same. Here we are in the domain of fantasy, which in this case takes two impressions to be separate, though the stimuli

involved form a unity. If we now recall the examples (*cf.* p. 138) where a figure is only recognized again as such when it is also redisplayed on the same ground (of the familiar colour), and where the two colours are therefore firmly coupled together, we find an example of fantasy in perception having a different effect, in that here it takes a pair of impressions as a unity, when as stimuli they represent two separate visual objects. It should be noted that no conceptual thought is involved in either process; and this for the simple reason that there is no knowledge at all of the possible structure. In both cases we are concerned, rather, with a sort of automatic structuring process in pure sensory intuition, with the aid of fantasy; the sensation being analytic in the one case and synthetic in the other. Thus the shapes we see are plainly not wholly created in the act of apprehension. For when we are contemplating a shape, we can begin by attending to a small portion only; but in doing so we may notice something happening independently of us (proceeding from the other parts) in the whole visual field of which the section we are looking at somehow forms a part.

Some of our cases completely lacked this capacity, to link together contents separately presented in contiguity or succession, and to view them as interconnected. They were therefore devoid of visual fantasy. It was typical of these cases, moreover, that fantasy also played no part in their former sensory activities, so that even when blind, for example, their powers of orientation had generally been poor. Nor did they ever learn to see properly, and were therefore justly described by their chroniclers as feeble-minded. Their weakness of intellect is to be discerned precisely in this want of fantasy, this total lack of any talent for combination. And there is therefore some warrant for asserting that, without the participation of fantasy, vision itself is but a mutilated affair. For fantasy represents the truly creative and progressive element, not only among our patients, but also in the life of every normal-sighted person.*

A still larger number of variant interpretations of the same sets of stimuli would undoubtedly have been exhibited in many of our patients, if circumstances had allowed them to be left entirely to their own subjective inclinations in the matter, without regard for time; and without anyone attempting to guide them from the start towards objective validity of judgement, and so in a sense restricting them. It was clearly evident in several cases (Moreau and Schnabel, for example), how their

* Compare the remarks of Wittmann (1) on this point in his section *Über Perzeption und Apperzeption* (pp. 462 ff.).

reluctance was partly due to the necessity of having to familiarize themselves with some objectively subsistent entity. And there is no comparing the greater pleasure the patient takes in his visual learning, once he has a certain basis from which he can go on to build up his visual world for himself, in the full emotional exercise and indulgence of his fantasy. On getting results for himself in this fashion, the patient takes a greater interest in the data of his new sense, works at them more assiduously, and hence also makes quicker progress in grasping the shape of visual objects (pp. 125 f., 128).

In every act of perception, the new judgement reinforces what is already lodged in memory; and on each occasion some further constituents of the shape are newly registered, which facilitate recognition of the object the next time it is seen. The process of registration is greatly assisted if the patient is allowed to examine the object, not with the eyes only, but also with the other faculties at his command, and so can take in all its aspects, in order to form an idea of the whole which later makes the help of these other senses unnecessary.

In order to grasp a larger whole as a unitary total shape, it is naturally very important that the patient should have gradually become more certain in the use of his eyes, through improved fixation and visual acuity. He must also have gradually learned to enlarge the objective and subjective boundaries of his visual field, so that in traversing a shape by eye, for example, he is already prepared for what he is just about to see. By using the peripheral areas of his retina he must learn, as it were, to 'foresee' the next thing his eyes are coming to, and already to make use of it in putting together the fancied shape of the whole. Only then will he be able to take in a larger area at a time, and will also learn to relate his successive shape-perceptions together in space and to combine them into a spatial image of the whole.

Once equipped with a few complete images of the various major forms, and with a consequent knowledge of the main structural schemata, such as 'round', 'hollow', 'angular', 'straight', 'curved' and so on, it becomes increasingly simple to perceive shape, not only in familiar objects, but also in those that are new. The patient finds fewer and fewer objects for whose structure he cannot find analogies of some kind in his memory, which guide his interpretation in a definite direction.

The outcome of our evidence on this subject may be summarized as follows: the perception of visual shape is a temporal process, and this not only at the patient's first attempts to see, but also later, when the visual apparatus has so far developed that its effectiveness is scarcely dis-

tinguishable from that of a normally sighted person. However brief and automatic it becomes, the act of perception remains essentially unaltered in its temporal structure. The patient does not take in everything at once (though everything is given to him at once), but notices the mutual relation and contiguity of the separate parts; he perceives a succession of views forming part of a whole that he is himself obliged to create by shifting his gaze; in so doing, however, he becomes aware of the conjunction of the parts in the whole.

From the first visual trial up to the fully developed perception of spatial shape, the whole course of learning is a process of organization on the patient's part, in which he tries out many different methods and gradually builds up all the functions whose final outcome consists in our ability to 'see'. In the course of this build-up there are repeated changes in the impressions he receives from visual objects, and the ideas he forms of them. From this it appears that the interpretation of a shape *qua* stimulus need not necessarily result in a definite and precise structure, represented in the stimulus itself and conveyed as a copy to the eye. For the same presented stimulus may on occasion be taken in a whole variety of different ways. The result in any given case depends on the interpretative powers and inclinations of the individual patient. It is not unambiguously forced upon him by the stimulus itself.

There is also a succession involved in the process which leads to the visual perception of solidity. Just as, in looking at a surface, the patient perceives a succession of views, relates them together and unites them into a collective picture, so, in moving round an object, he also obtains a succession of images, as of surfaces. He then rounds out the image in relief. This plastic image is not, however, a mere intellectual product of his knowledge, but a genuine product of his vision, namely of the shift in his point of view, which he is at liberty to alter. The elements coalesce into an impression of solidity (*cf.* p. 267 f.).

Temporal succession, one may say, is a characteristic feature of vision in general, for we also encounter it in the perception of depth. When looking fixedly in a definite direction, the stimulus does indeed present things all at once, as lying behind, and partly concealing, each other. But in order to take conscious note of this, my gaze must either 'pierce' outwards, in temporal succession, from my own vicinity into the distance, or, conversely, must revert from the distant to the near at hand.

Before proceeding to draw general conclusions about spatial vision from visual learning in our patients, it seems advisable to give yet another brief summary of how the patient gains his acquaintance with

visual space. He meets it at the outset only as an indefinite sensory experience of depth. He cannot fixate with both eyes at first, and has to learn this. The operation has removed the lens, so he cannot accommodate. For fixation and attention he must learn to converge, however, and thereby comes to see things in relief.

The patient, at first, has no visual memory, even for colours, in most cases. He acquires it gradually, and only so is he enabled to recognize things again, or to compare a present object to a previously seen one.

The perception of visual objects is initially confined to qualitative features and only gradually extends to shape proper, by various stages, which the patient must organize for himself, and which may therefore differ from one case to another. This progressive task of interpreting the sensory visual impressions is facilitated by the gradual elimination of organic defects, the pre-operative development of mental capacities, and by the schematic knowledge of 'space' that has likewise been gathered before the operation. This gradual penetration of visual space calls, not only for mental agility, but above all for the activity of the whole man. To begin with, the subjective spatial field is progressively enlarged. Only by systematically coordinating visual objects in their relation to one another, and to visual space, does the patient himself develop the subjective awareness of space imprinted on his senses into a conception of its objective reality. At first this objective space is located behind and beyond the subjective field of vision, and only an extension in thought enables it to overlap the boundaries of the sense-given spatial field; as was to be observed in a number of our cases.

So far as the theory of spatial vision is concerned, our research into the case-reports has yielded, on the one hand, renewed confirmation of long-established facts; but on the other it has also provided corroboration and deeper understanding of relationships that have only been disclosed by more recent investigations. They may be summarized as follows:

(1) The impressions specific to vision are brightness and colour. Vision is at first purely phenomenal in character.

(2) The perception of colours is inseparable from that of surfaces; the colour-patches are seen extended, and in a uniform middle distance, appropriate to the individual vision of the patient.

(3) Thus visual space is neither a sensation on its own account, nor a qualitative idea, nor the product of a synthesis of impressions, nor an intellectual abstraction; it is a 'form of intuition', given

along with the sensory content in every act of vision, and inseparable from this.

(4) Once the colour-patches have been consciously identified as *visual objects*, they also begin to be consciously located in space; gross differences of depth are perceived, and practice leads to a developing estimation of depth.

(5) Objective space is not a primary datum, but is only secondarily acquired from subjective space, by grasping the positional relations of visual objects to one another, and within visual space. Since all the parts of visual space cannot therefore be objectified to the same degree, they do not all have the same objectively spatial character.

(6) Both spaces, subjective and objective, are progressively enlarged, the subjective first; objective space can only be made to overlap with the subjective by an effort of thought.

(7) Given that attention is present, the stimuli impinging on the visual organ from an objective shape merely occasion the act of perception as such, but do not determine its outcome. The idea of shape is not due to a dynamic effect of the stimulus on the visual organ; nor is it due to an alleged passively reproduced transmission of the stimulus, occurring simultaneously at a purely physiological level; it is the outcome of a process of conscious interpretation in time.

(8) The apprehension of shape is thus exclusively a matter for the perceiving individual, and is therefore dependent on the vigour of his intelligence and personality.

(9) The final development up to the fully formed idea of shape involves a series of transitional forms as intermediate stages, which develop one from another, and are liable to vary between individuals, since it is the individual who himself creates them.

(10) The process of apprehension is in every case successive; it can, however, be considerably abridged by increasing mechanization, which is promoted by the possession of memory-images and structural sequences.

(11) This mechanical abridgement is accompanied by a progressive shift in the proportion of purely sensory content relative to the still remaining interpretative activity required for perception proper.

(12) The perception of movement again has no necessary connection

with physiological reception of the stimulus. To anyone looking fixedly in a certain direction – and especially the newly sighted – a movement occurring in this region may be registered as an alternation of different degrees of brightness.

CONCLUSION

The account just concluded took its starting-point from the celebrated problem of Molyneux. Great importance was attached to this problem by his contemporaries, and also by later inquirers. It is of some interest in our present context, in so far as the wording of the question shows that even Molyneux plainly had the idea that tactual objects were ultimately given in some intuitive way to the blind man's mind, in a certain compact and substantial fashion; a notion that may still be fairly widespread even today.

Apart from this question, the main interest in the cases of the period was centred on the thesis put forward by Berkeley, that visual objects must appear to the patient as if they touched his eye. Our present analysis of a large number of examples should have served to provide an answer to both these questions.

It has been shown, furthermore, how instructive these cases are for the psychology of space, and indeed for psychology in general. We have been led to conclude that by tactual perception alone the patient is unable to acquire an awareness of space, and that this is solely dependent on visual perception. We were driven to this conclusion, because it repeatedly emerged throughout virtually all the cases, that everything spatial presented to the patient after the operation is entirely new to him, and that no bridge, however narrow, can be opened up to it from his tactual mode of existence. This knowledge is still more forcibly brought home to the patient, in that this novelty is not conveyed to him forthwith as an effect of his visual stimuli, but has to be worked out at length by the subject himself. For this very reason, the patient's adaptation to his new surroundings often takes a highly dramatic form, and leads to violent conflicts.

Just how novel everything appears is particularly well shown by the fact that, in taking stock of the visual world, the patient makes no use of his customary methods of apprehending tactual impressions, or of the knowledge thereby attained, but learns everything anew. This is the more significant, in that – as shown in detail – he has to take part himself in the shaping of his visual world, and under such difficult circumstances that he immediately makes use of any assistance he can discover;

and so would undoubtedly call upon his tactual experience of space if he had any to offer.

The extent of the blind man's actual exile from spatial reality also appears from this, that on discovering himself situated, along with other men, in the order of visual space, his personal life takes on entirely new forms. He now knows, what it was previously impossible for him to picture, how another person could watch over his acts and omissions without laying a hand on him. He now gives up many habits he could not be broken of earlier, because he is suddenly ashamed of them. He suddenly takes an interest in his clothes, attends to his hair, and pays heed to the impression he creates upon other people. In former days objects were of little interest to him (so far as they were not edible), since their shapes could not stir his senses, and the sighted world's standards of value seemed to him an illusion. But now a sifting of values sets in. On perceiving the shape of things by his senses, he acquires an attitude towards them; desires for possession make themselves felt; his thoughts and wishes are mightily stirred and some few of the patients are thereby led into dissimulation, envy, theft and fraud. Others give evidence of aesthetic interests that they never displayed before. It would certainly have been tempting to explore all these attitudes in the light of our material!*

I am well aware that some major findings, to which I have been led by analysis of my material, will meet with contradiction in other quarters. Steinberg (4) and Petzelt (6) have already disputed the conclusions of Gelb-Goldstein (3) and Wittmann (1). They have also been especially critical of the work of Ahlmann (2), who, after many years of total blindness, came to the conclusion that no awareness of space can be derived from purely tactile experience. But in view of the empirical facts reflected in the reports on which I have based my analysis, the arguments of these two authors have inevitably seemed to me to smack too strongly of introspective psychology; so that I could not expect much profit from controversy with them. Besides, it would merely have diverted me from the true object of my inquiry, which was to give the most reliable and exhaustive account I could of the facts about pre- and post-operative spatial perception in the congenitally blind, as they are set down in the reports.

The results we have arrived at represent, in the main, a confirmation

* In view of the many-sided interest of the reports to every branch of psychology, I should consider a documented collection and edition of them to be well worth while.

of the opinions of Hagen, Gelb-Goldstein and Wittmann. But their significance is not limited, of course, to the fields of philosophy and psychology. They should also be of special importance to educationists, and in planning courses of instruction for the blind.

One thing in particular should be obvious by now, namely that the task of restoring sight to a congenitally blind person is equivalent to that of ushering a man from a given mode of life into a new and fundamentally different one. It can succeed only if the doctor knows how to overcome the numerous personal and intellectual obstacles confronting the patient, and to spur his faculties into the greatest possible activity. For the patient needs this activity and emotional tensity if he is gradually to build up the successive transitional forms that he has to create in gaining a grasp of the spatial. The reports give evidence, in this very connection, of the weight of responsibility falling on the doctor, on his psychological knowledge, and on his educational ability. But they also reveal that in many past cases a great deal has been lost for want of any kind of method. If only a few suitable cases (such as those of Miner, Francke and others) had had systematic pre-operative training in introspection (the operation being deferred accordingly) and had also been questioned afterwards! It would then undoubtedly have been possible to reach far more detailed conclusions about their pre-operative tactile experience, based on a comparison between their serially experienced methods of apprehending the spatial, before and after operation. But since, in present-day civilized countries, we are advancing ever more rapidly towards complete control over the health of every member of the population, such cases may be expected to become increasingly rare. The value of the existing reports therefore becomes all the greater.

If any doctor should be called upon to perform an operation of this type, the foregoing account may help to suggest ways of ensuring its complete and total success.

APPENDIX (1959)

SIGNIFICANCE OF THE WORK FOR RELATED DISCIPLINES

(i) Psychology

A. H. RIESEN

The original publication in German of the von Senden monograph was not widely available to psychologists. Some took note of it only to find that its conclusions were at variance with the upsurge of emphasis at that time on inborn determinants of visual perception. From biologists and Gestalt psychologists came the objections that anatomical structures and physiological processes should guarantee proper visual functions following normal growth and absence of injury. The complications that are often associated with congenital cataract and the subsequent interference by surgery are extensive in some of the cases reported, and the original reporting itself left much to be desired. Psychologists were not alone in seizing upon these difficulties to explain away evidence which contradicted the prevalent views about form and space perception, nor have all of the specific points of argument been resolved.

In 1949 D. O. Hebb, in *Organization of Behaviour, a Neuropsychological Theory*, reported experiments on rats and chimpanzees which gave credence to some of the Senden interpretations of the clinical data. Experimentation has continued, extending, qualifying, and serving to reformulate a growing body of knowledge into an extensive comparative psychology of visual development. The theoretical issues raised by Hebb and, from a somewhat different set of assumptions, by Hayek (*The Sensory Order*, 1952) are stimulating new research which gains its relevance to the problem of the origins of human space perception through von Senden's review of cases and his interpretations of their significance. The relatively prompt response of the human patient following surgery to cues of visual intensity and hue are receiving confirmation in the laboratory from work on animals reared in darkness or in diffused light. That infra-human mammals also share with man much of

the dependence upon a period of perceptual learning before they may utilize cues from shape and spatial relations and movement is becoming clearer with each well-controlled experiment. Even the protective eye blink to an approaching object and the visual placing response, once commonly asserted to be reflex in nature, are elicited in the cat or monkey only after a minimum of several hours of experience. Gross postural activity in the well-articulated visual environment is necessary for the appearance of visual placing in the cat. Protective eye blink responses depend upon a series of conditioning trials. These are conditioned reflexes in the classical Pavlovian paradigm, never developing in animals whose visual experience is separated from any occurrence of certain paired stimuli. The visual conditional stimulus of an approaching object must be combined repeatedly with an adequate stimulus for the eye blink, which in the normal course of experience is a tactual stimulus to the face, eyelids or cornea.

While some of us who are working in this field are accepting the generality of the principle that the more refined the spatial visual discrimination the more it is dependent upon earlier learning, many points of disagreement remain. Some psychologists still question the general statement, others are concerned with the problem of how adequate later experience is as a substitute for that of the early weeks of life. Others of us have gone into the question of transfer of perceptual organizations from those developed through the use of one eye to the partially shared nervous system of the other. While von Senden did not raise this issue specifically, Hebb saw the implications of the human data for the problem of interocular equivalence. Here again the laboratory studies are confirming the emphasis upon spatial and form vision which von Senden's cases provide. An 'inexperienced eye' of a young cat serves well in place of the other when visual intensity is the relevant cue and visual orientation in space is not required. This is true even when dark-rearing and an opaque occluder have been combined to block out all light from the second eye. Comparative studies are revealing some differences between fish, birds, and mammals in the responses to initial visual stimulation, whether monocular or binocular. Equally significant, however, are the visual reflexes which are common to the vertebrates and which play a role in the development of visual discriminative behaviour following the organism's release into a visually structured environment. Here the oculomotor responses are clearly seen as prepared to participate immediately, dependent in a significant measure on the stage of intrinsic growth processes already achieved.

A question often asked in relation to the cataract cases and the animal experimentation concerns the health of the visually deprived retina. Von Senden has himself concluded that this is a serious aspect of the course of post-operative improvement. Studies of this problem have revealed some chronic changes in the protein content of neural cells of the retina which fail to correlate with visual performance in the cat, but which, in the chimpanzee, proceed to an acute stage in which ganglion cells disappear and vision vanishes. This is not the place for a detailed discussion of these experiments. They clearly add to the factors that must be kept in view when a complete account of visual development and its relation to visual stimulation is written. The work is extensive enough already to show that cytochemical variations in retinal cells may cover a considerable range without being reflected in concomitant alterations in visual function. The patient with cataracts probably remains well within this range. This would place the core question regarding structural bases for visual space perception almost certainly within the more central systems of the brain.

The monograph by von Senden has initiated thoroughgoing re-examinations of psychological theories of perception and of learning which are continuing in current papers and symposia. If switchboard or reflex arc concepts lingered on into the nineteen-fifties they are now obsolete or so complicated as to be unrecognizable. The isomorphism of Gestalt theory has been dealt a finishing blow by the facts which are now bringing on the newer neuropsychological models. It is indeed fortunate that Peter Heath's excellent translation of von Senden's fascinating, and once almost incredible, account will be available to help set the requirements for models of neural modifiability.

If psychologists, or philosophers as well, find some portions of the von Senden monograph out of touch with current concepts or at variance with established fact, this should not lead to the rejection of the whole. Some there are of us who would not accept the entire treatment of non-visual space perception, and especially not, perhaps, the emphasis upon its piecemeal nature. Part IV of the work draws certain vague conclusions about subjective awareness in early post-operative patients that are difficult to check or interpret. The work does not actually support, as some have contended, an extreme empiricism. Von Senden points out discrepancies and uncertainties in his own conclusions about an initial capacity for judgements of relative depth. These and many other points of detail remain to be clarified, which fact emphasizes the central lesson of the book: visual perception cannot be quickly understood by either a

nativistic nor an out-and-out empiricistic solution. Its origins are rooted in phylogenetic as well as ontogenetic development and our knowledge of how far intra-organismic growth can proceed before environmental support must be added to refine the function is still a matter that von Senden leaves to a series of educated inferences. He has shown us some crucial areas in which these inferences must yet be improved.

(ii) Anatomy and Physiology

J. Z. YOUNG

In spite of the obvious interest that mankind takes in itself, it might be said that the language for describing our most interesting features has developed only slowly. Literature and poetry, it is true, provide a means readily understood by all for describing human lives. Perhaps, because of the very fact that they are so closely tied to life, they remain in a curious sense primitive and inexact forms of communication. To the scientist it seems that much is gained by the greater precision that is achieved by using instead of everyday words an arbitrary symbolism such as that of mathematics or chemistry. This puts limitations on the area that can be treated and the number of persons with sufficient time to master the techniques, but the very fact of using a new language leads to the discovery of new facts. Such techniques have revolutionized physical science, but biology and medicine still continue to struggle along with, in the main, ordinary language.

The task of finding an exact biological language that will satisfactorily describe what goes on in so complex a system as the human brain is clearly vastly difficult. Psychologists and neurologists have attacked it with what weapons they could find, and are perhaps now beginning to produce at least the outlines of a satisfactory scheme. Yet anyone who has tried to teach the anatomy and physiology of the brain to medical students must realize that the ideas they carry away about the structure and functioning of the higher nervous centres bear little relevance to actual human life and provide small basis for therapy of this, our most important organ.

We teach that the pyramidal and stellate cells of the cortex are arranged in certain layers; that they show certain electrical activities, and that individual parts of the brain are related to particular receptors

or motor activities. We can even state that certain parts, such as the hypothalamus, are concerned with appetive drives and perhaps, vaguely, with 'emotion'. But, in general, we have to be content with labelling most parts of the brain as being 'coordination centres' or 'association centres', and leave the student to go out into practice with that. We can give no picture of how the web of interlacing axons and dendrites of the cortex somehow carries an imprint that enables us to recognize a face not seen for thirty years. What is this print? In what code is the information carried and how is it registered in the brain during learning?

Much disillusion with solutions to this problem comes from lack of appreciation of its complexity. It is most unlikely that any reasonably satisfactory answer will prove to be simple enough to be understood by anyone with less training and ability than is acquired by a good physicist. One of the tragedies of the distribution of human effort is that so few really able brains study brains.

However, we can at least use what powers and knowledge we possess to try to formulate some possible approaches to the problem. And here clearly the first requirement is to try to identify and locate it. Where and when in the life cycle are the characteristic features of higher nervous centres established? We know that for the spinal cord this occurs before birth by the laying down of suitable neural pathways under the control of heredity. Even here, however, we may notice that a certain 'maturation' occurs after birth and is influenced by the exercise that is provided by use. In many parts of the nervous system, as for example the tectum opticum of a chick, heredity lays down the main outlines of the organization, but if there is no function, as when the eye is absent, the nervous centres later regress.

When it comes to the question of the development of the higher parts of the brain, the problem of the interaction of the effects of heredity and use becomes even more difficult. The nervous apparatus of the cerebral cortex seems, to superficial observation, to be nearly fully developed at birth, or shortly afterwards. The number of nerve cells is already fixed at birth, and even the number of branches and twigs that they show is nearly as great as in the adult, at least as judged by light microscopy. It may be that, with the much greater powers of the electron microscope, subtler changes will be seen.

For it is clear that into the brain of the child or young animal a great deal of information must be placed before it is possible to conduct what seems to the adult to be the simple operation of 'seeing'. The great merit of the collection of cases that Dr von Senden has made is to show

the extraordinary extent to which we have to learn to see. In a sense this is obvious enough from the slow progress made by normal children, but study of them alone does not, of course, tell us how much of their development is due to 'maturation' under the influence of heredity. The cases here described constitute a controlled experiment on this question, and they tell us that it is only by use and experience that the visual system develops its powers.

Perhaps even more interesting is the further question whether the practice of vision allows the development of the faculty, as it were, by the general exercise it provides, or by the information that is stored as a result of each particular occasion of seeing. Here the observations are less decisive. Indeed, the question is not easy to propose in answerable form. It is, however, implicit in much of the discussion throughout the book, for instance in the use of a 'schema', or the asking of the question whether 'a truly spatial idea of shape is involved'.

How are we to try to grasp the nature of the mechanisms involved? I cannot help thinking that von Senden makes this more difficult for himself in places by the dualist approach that he adopts. He speaks of the first vision as a 'purely physiological process', of a passive nature, as if the later stages were something different and not 'physiological'. Indeed, he further speaks of 'passing from sensation to perception'. It is extraordinarily difficult to avoid such a treatment, just because we have no clear idea of what brain processes are involved in, say, the recognition of shapes. Until we know in what form representations of outside events are stored in the memory, it is difficult to begin to talk about how we gain access to them in order to make comparisons. It is tempting to suppose that some specific mechanisms or visual habits are built up, for instance the following of contours, recognition of angles, estimations of area. These would then be 'switched in', perhaps successively, in attempting to find recognizable features that can be compared with invariants identified in classes of figures seen previously. Some such process may indeed occur, but there is much in the reports to suggest that a great deal has to be learnt individually and in detail. The 'mechanisms' of search, which must first be learned, are perhaps fairly simple, say, fixation, eye movement, following of contours. For a long while each object is recognized just as itself. Of course generalization and classification occurs, but perhaps it too remains, as it were, restricted to generalization about the particulars that are experienced rather than the learning of general rules. In fact the mechanism does not depend upon the setting up of elaborate systems for computing precisely the

shapes of any new figures, but on the formation of analogues in the brain with which the new information is compared.

This, at least, provides some clue that the anatomist and physiologist can pursue. It finds support from the regular arrangements of the cells and their processes that can be recognized in the learning systems of such simpler animals as the octopus. It might seem fantastic to look for such regularities as the basis of our own memory system. However, there are some very suspicious similarities in the retina and optic system of all animals that can discriminate shapes – for example all are layered systems, with large numbers of small cells with processes diverging to varying distances.

The question is perhaps hardly in a state where it can profitably be discussed in relation to clinical data. But, the fact that some processes of organization must go on before use can be made of the eyes can only tempt the physiologist and anatomist to try to ask what these processes are. They may consist fundamentally in changes of threshold and excitability, as well as the formation of new connections and, perhaps, the breaking of old ones. It is not, however, only the basic processes but the way that they are organized that one so much wants to know in order to interpret a careful analysis, such as is here provided, of the stages by which a useful computor of visual shapes is established in the brain.

(iii) Philosophy

G. J. WARNOCK

1. A very great deal of philosophical enquiry has been concerned with the elucidation of the relations between the content of our knowledge, and the modes of its acquisition and verification – alternatively, between the nature of our concepts, and the ways in which they come to be formed and are applied. Those philosophers at least who have subscribed to some form of 'empiricism', rejecting any easy recourse to the idea that either concepts or items of knowledge occur in human beings innately, have necessarily held that what there is in a human mind is ultimately determined, and can best be understood by examining, the means by which it got there – by examining, that is, the modes and varieties of sense-perception and of learning by experience. The cases

collected and described in the present book are relevant to a particular case of this general preoccupation – to the question how the concept of Space, and spatial concepts generally, are related to the modes of perception in which they are acquired and employed.

The peculiar difficulty in this particular case is that, on the face of it, these modes of perception are very complex and diverse. They appear to include, broadly, both sight and touch, and moreover of these the so-called sense of touch is notoriously susceptible of complex subdivision, both on physiological and epistemological grounds. Thus there is ample material here for confusion. We have an instance, a leading instance, of a class of concepts application of which is determined by *multiple criteria*, the connections between these criteria being very far from obvious. It is by no means easy to distinguish between those questions that are to be answered by argument and analysis, and those that can be resolved only by observation and experiment; it is most difficult to decide what experiments can usefully be made; and, in the face of observations very often collected somewhat at random, there is ample scope for disagreement about what, if anything, they prove or disprove. Von Senden's work provides illustration of all these difficulties.

2. It was Locke, at the instance of his Dublin friend William Molyneux, who, in the *Essay Concerning Human Understanding* (1690), first brought these questions into philosophical currency. His account, in the idiom of that time, of the 'idea' of Space was neither lengthy nor elaborate. The idea of Space he classified as a 'simple idea', acquired 'both by our sight and touch'; and it did not occur to Locke to question that one and the same idea was 'let into the mind' in these alternative ways. Moreover, in his discussion of the 'simple modes', or modifications, of the general idea of Space – for example distance, volume, shape, size, position – he was content in the view that these are unitary concepts with alternative means of formation and application. Nor was he led into any doubts on this point when Molyneux convinced him that 'a blind man, at first sight, would not be able with certainty to say which was the globe, which the cube, whilst he only saw them; though he could unerringly name them by his touch' (Bk. II, cap. 9, sec. 8). For Locke seems to have held that the formerly blind man's difficulty would be merely that of being unable to interpret correctly the visual clues to the application of the spatial concepts that he certainly possessed – as if, one might say, while knowing very well what spheres and cubes respectively were, he would be ignorant only of what they looked like.

It is to be noted, of course, that Locke here tacitly assumes that know-

ing what a sphere, for instance, *looks like* forms no essential element in possessing the concept of a sphere. In this view Leibnitz explicitly concurred on the ground that the essence of spatial figures is purely geometrical, and that vision is in no way essential to the study of geometry.

3. Molyneux's problem was next taken up at length by Berkeley, in his *New Theory of Vision* (1709). With the supposition that a man previously blind would be unable, on first coming to see, to distinguish and identify shapes Berkeley fully agreed. But this, he maintained, should be attributed to the fact that the 'ideas' of sight were totally distinct from those of touch and sensation – there could be no such thing, he held in opposition to Locke, as an idea common to two or more senses, since each of the senses had its 'proper objects' peculiar to itself. The true objects of sight, Berkeley held, were merely 'light and colours'; these were indeed visually extended, but the ideas of visual extension and of tactile extension were totally different. (Here he directly controverts the opinion of Leibnitz.) The notions of Space and of spatial properties generally, Berkeley writes in this work, are acquired solely from the sense of touch – from felt contact and felt movement; for thus alone are we actually made aware of figured, moving, extended bodies 'in circumambient space'. Strictly, the ideas of vision are no more than signs of the presence of such bodies, though, from long experience of the constant and reliable association between the data of sight and touch, we are apt both to say and to believe that we see bodies themselves. But, on this view, a man deprived by blindness of this long experience would, on first coming to see, be confronted with visual signs that he would be wholly unable to interpret – seeing, for him, would be like a strange new language he had never learned. Since the correlation between sight and touch is in Berkeley's view purely inductive, there could be no question of his grasping at once any connections at all between his former experience by touch of objects in space and the strange new field of visual data made suddenly available to him.

Now although one may well accept, and observation seems to confirm, the conclusion at which Berkeley arrives as to Molyneux's problem, it is evident that the grounds he relied on were highly dogmatic. It is of course not a matter of dispute that feeling and seeing are quite distinct; but Berkeley offers no reasons at all for assigning all spatial concepts strictly to the former alone. It appears to be analytic in his terminology that the data, the 'proper objects', of touch and of sight cannot be the

same, but this in no way justifies the quite different assertion that spatial *concepts* must be proprietary to one particular sense. It seems that Berkeley's insistence in the *New Theory of Vision* that spatial concepts are acquired only from the sense of touch is connected with the doctrine put forward there that the sense of touch alone gives direct acquaintance with physical objects. But this unargued doctrine Berkeley himself very soon abandoned, and he even asserted later that he had never seriously believed it. But if not, there appears to be no reason at all why, distinguishing as he does between touch and sight, he should assign all spatial concepts exclusively to the former. Unfortunately his reconsidered account of perception, in the *Principles of Human Knowledge* (1710), contains very little further discussion of this matter.

4. It is curious that von Senden reveals in the present book a conviction directly the opposite of Berkeley's; and I must add that it appears, in my opinion at least, hardly less dogmatic. Namely, he shows throughout a very strong reluctance to concede that concepts formed by the congenitally blind can be accepted as, strictly speaking, spatial concepts, or that such persons can be 'aware of space itself as a reality'. It may well be asked how a philosopher can venture to describe this attitude as dogmatic, since it is put forward as a psychological thesis based on very close study of recorded cases. My reason for doing so is that the thesis in question does not appear to me to be required by the evidence, and indeed at key points it is manifestly reinforced by extraneous considerations of great philosophical interest, but most uncertain authority.

Von Senden's main thesis seems to be founded chiefly on four diverse grounds, which we must briefly examine.

(*a*) He appears to be inclined to argue that, if the congenitally blind were to possess genuinely spatial concepts, their ability to identify, and even to represent, spatial forms ought to be better than the records show it to be. (See for example pp. 69 ff.) But this lacks cogency. Plainly one must admit that total lack of vision is a very grave handicap in identifying, describing, and dealing with objects in space. This, however, so far from requiring the conclusion that the blind man has no genuinely spatial concepts at all, seems on the contrary to make it understandable that, and why, he should sometimes have great difficulty in correctly employing the spatial concepts that he has.

(*b*) Von Senden is also inclined to maintain that, if it were the case that 'true' spatial concepts could be formed by the congenitally blind, then it should *not* be the case, as the records show it to be, that such

persons on gaining sight are at first, and sometimes for long periods, wholly at a loss. 'It must be insisted', he writes (p. 66), 'that a blind man, however he may have formed his awareness of space, if he has one, should not find himself confronted after operation with the space of sight as something entirely new and completely incomprehensible to him.' But this is not, of course, a view that is in any way based upon evidence; it is simply the assumption that knowing what spatial figures *are* must be deemed to include knowing how they *look* – so that, if it appears that a man does not know how they look, it is to be concluded that he does not really know, and has never known, what spatial figures are. But in fact this doctrine is neither self-evident, nor even very plausible. Is it any more persuasive than the contrary opinion of Locke? May one not know what spatial figures are from knowing how they feel?

(*c*) There also appears in this book from time to time what can only be described as a question-begging assumption – namely, the simple assumption that *real* awareness of space can only be visual. We read, for example, on p. 106 that, as indeed is obvious, spatial perception in the blind is different from that in sighted persons; and the conclusion that it cannot properly be called spatial at all is there supported, not by any further appeal to the evidence, but by the simple assertion that 'visual space has always constituted the normal space governing the origin and gradual change of meaning of spatial words'. But this assertion is questionable both as to truth and as to relevance. Since 'normal' people can both see and feel, how is it to be proved that spatial words for them owe their 'origin' exclusively, or even primarily, to visual experience? And even if this point were conceded, no more would follow from the concession than that the blind cannot form spatial concepts in the normal way – which is, of course, a long way from the conclusion that they are not really able to form such concepts at all.

(*d*) Finally, von Senden seems to rely in his early chapters on the point that the experience of blind persons can be described, not in terms of apprehension of space and of bodies in space, but in terms of learned patterns of repetition and reproduction in sequences of tactile and kinaesthetic sensations. It is said that their experience really may amount only to this, though they may learn from sighted persons to make some – in principle misleading – use of a spatial vocabulary. But against this point it can easily be argued that visual experience too can be described without any 'normal' spatial interpretation, for instance in terms of two-dimensionally extended patterns of light and colour. (Berkeley would have held that, strictly speaking, this is the only

correct mode of description of visual experience.) But in neither case is there any immediate inference from the possibility, to the propriety, of adopting such restricted idioms of description. A possible mode of description might well be quite inappropriate.

5. Although I thus believe on philosophical grounds that one may, and probably should, dissent from the author's own interpretation of the cases he has assembled, I do not wish to give the impression that small value attaches to his work. On the contrary: uninformed speculation on these matters in the manner of earlier philosophers is plainly somewhat idle, and to have collected so vast a range of facts, imperfect though the records may be, is a considerable service. But the problem concerning the spatial awareness of the blind is far too complex to be settled by any survey, however extensive, of 'the facts', and certainly must always involve issues that fall within the purview of philosophy. What blind men say about Space and objects in space, is a question of fact. But at once it is important, as von Senden rightly points out, to remember that blind men learn language from sighted persons and may not, though they have thus learned to say the usual things, attach quite the usual senses to what they say. So already there is room for dispute in interpreting our findings. Then there is the other, and doubtless more important, factual question: What can blind men do? But here it is a task demanding great skill and ingenuity to devise just those practical tests that will be genuinely revealing, will beg no questions, and will be as little indeterminate as possible in evidential force.

But if now, supposing these difficult factual questions to be adequately answered, we go on to ask: Do blind men, strictly speaking, possess spatial concepts? – then at once we are involved with the purely *conceptual* question of what it *is* to possess spatial concepts. This divides into a number of subsidiary questions. What is the connection between the geometrical definition of a cube, the visual appearance of a cube, and the feel of a cube? Are sensible 'images', as Leibnitz thought, totally unnecessary here? Unnecessary for what? What would be the predicament of a being who could see but not feel? If correlation between the data of sight and touch were to become wholly deranged, to which sense should we attach authority as against the other? Should we then think of ourselves as *seeing* the world to an accompaniment of random and irrelevant sensations? – or as *feeling* the world to an accompaniment of merely distracting visual phantasms? Or might we take either line, depending on the detailed circumstances of the situation supposed?

6. It may be thought that these are idle speculations, as indeed they are in the absence of supporting detail and argument. Furthermore, even if the situations supposed were to be set out in full concrete detail, it might still be impossible to answer such questions with much confidence. But it is such questions as these that have to be considered if we wish, so to speak, to anatomize the concept of Space – their complexity is neither greater nor less than that of the concept itself. Thus there is plenty of conceptual spade-work here for philosophers to undertake, or for psychologists operating in a philosophical role. Only thus can one be in a position rightly to judge exactly *what* is established by such records as von Senden has assembled, or indeed by any observations that may subsequently be made. For here, if anywhere, the record does *not* 'speak for itself'.

LIST (

No.	Year	Age and Sex	Place of Operation	Author and/or Surgeon
1	c. 1020	30 m.	Arabia	AMMAR
2	1695	11 m.	Zürich	FREYTAG
3	1698 / 1704	18 m.	"	"
4	1709	20 m.	Newington, London	GRANT
5	1728	13 m.	London	CHESELDEN
6	Before 1749	m.	Puiseaux (Not operated)	DIDEROT
7	Before 1762	Twenty-two cases	Paris	DAVIEL
8	1764	22 f.	Lyons	JANIN
9	1777	14 f.	Vienna	(MESMER)
10	1783–1813	Fourteen cases	Vienna	BEER
(11)	1800	7 m.	London	WARE
12	1801	18 f.	"	"
(13)	1806	12 m.	"	HOME
(14)	1806	7 m.	"	"
15	1810	14 m.	"	WARDROP
16	1826	46 f.	"	"

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No.	Year	Age and Sex		Place of Operation	Author and/or Surgeon
17	1840	18	m.	London	FRANZ
18	1846	11	m.	Pavia	TRINCHINETTI
19	1846	10	f.	,,	,,
20	c. 1852	15	m.	Lausanne	RECORDON
21	Before 1855	9	m.	Leeds	NUNNELEY
22	1858	17	f.	Erlangen	HEYFELDER
23	1874	4	f.	Königsberg	V. HIPPEL
24	1874	7	m.	Berlin	HIRSCHBERG
25	1876	4	m.	,,	,,
26	1875	20	m.	Lausanne	DUFOUR
27	1875	17	f.	Bucharest	FIALLA
28	1876	10	f.	,,	,,
29	1876	25	m.	,,	,,
(30)	1877	16	m.	,,	,,
31	1877	7	f.	,,	,,
32	1877	15	f.	,,	,,
33	1879	5	m.	Innsbruck	SCHNABEL
[34]	1880	12	f.	,,	,,
35	1879	20	f.	Vienna	MAUTHNER (JAEGER)

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No.	Year	Age and Sex		Place of Operation	Author and/or Surgeon
36	1880	5	f.	Marburg	SCHMIDT-RIMPLER
37	1881	3	m.	"	"
38	1882 (op. 1849)	15	m.	S. France, place not given	MARC-MONNIER
39	1883	21	m.	Milan	ALBERTOTTI
40	1884	16	f.	Lyons	GAYET
41	1886	22	f.	"	DOR
42	1888	13	f.	Paris	DUNAN
[43]	Before 1888	38	m.	Not operated	"
[44]	1888	8	f.	Königsberg	FISCHER (SCHÖLER)
45	1890	7	m.	Breslau	UHTHOFF
46	1891	19	m.	Dorpat	RAEHLMANN
(47)	1891	14	f.	"	"
[48]	Before 1895	19	f.	"	"
49	1891	15	m.	Namur	GRAFÉ (BRIBOSIA)
(50)	1893	26	m.	Greifswald	FRANCKE (SCHIRMER)
51	1895	9	f.	Gothenburg	AHLSTRÖM
52	1895	5	m.	Lyons	VURPAS-EGGLI (GAYET)
53	1895	4	m.	"	"

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Innales médico-psychologiques, Paris, 4/1896.	165, 238
	46, 134, 142, 165, 239

No.	Year	Age and Sex		Place of Operation	Author and/or Surgeon
54	1891	2½, 3, 3½		Marburg	UHTHOFF
55	1893	3	f.	„	„ (UHTHOFF)
56	1896	5	m.	„	UHTHOFF (AXENFELD)
57	1897	37	f.	Not operated	UHTHOFF
58	1902	10	f.	Breslau	SEYDEL (UHTHOFF)
59	1902	22	f.	Iowa, U.S.A.	MINER (DEAN)
60	1903	30	m.	Glasgow	LATTA (RAMSAY)
61	1903	20	f.	„	LATTA (RAMSAY)
62	1904	33	f.	„	LATTA (RAMSAY)
63	1910	8	m.	St Étienne	LEPRINCE (MOREAU)
64	1913	15	m.	Bromberg	AUGSTEIN
65	1928	18	f.	Lincoln, Nebraska	Not stated ('GETAZ')
66	1931	22	m.	Philadelphia	Not stated (MOORE)

The following cases could not be dealt with in the present work:

(*a*) Owing to insufficient indication of source:

(1) The cases of Duval and de Gregoris, mentioned by Trinchinett [18];

(2) The cases of Baron Wenzel, mentioned by Home [13];

(3) A case of Hofbauer's, mentioned in Helmholtz's *Physiologica Optics*;

(4) A case of Prof. Wicherkiewicz in Cracow, mentioned by Augstein [64];

(5) A case mentioned in Busoni's *Von der Einheit der Musik*, Berlin 1922.

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(*b*) Owing to inability to locate them in any library:

(1) A description of individual cases of Daviel [7] and Janin [8], said by Janet (5) to be found in Rey-Régis: *Histoire naturelle de l'âme*, Paris 1789, Lyons 1789;

(2) The case of Zisman's in *Russky oftalmologichesky zhurnal* (*cf.* No. VI in the Addenda below);

(3) The sequels to their reports promised (but not published?) by Albertotti [39] and Schmidt-Rimpler [36];

(4) A case announced by Grafé [49], as being about to undergo operation.

No.	Year	Age and Sex	Place of Operation	Author and/or Surgeon
I	1896	8 f.	Irkutsk	ZISMAN
II	1904	18 f.	?	NOSHEVSKY
III	1920	29 m.	Military hospital in ?	AVIZONIS
IV	1926	16 m.	?	,,
V	1928	12 f.	?	,,
VI	1922	23 f.	Melitopolsk	ZISMAN
VII	?	Résumé of five cases	?	POKROVSKY
VIII	1958	52 m.	Wolverhampton	GREGORY (HIRTENSTEIN)

NDA

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* These items are summarized in: W. D. Ellis, *Sourcebook of Gestalt Psychology*, London 1938, pp. 12–16 and 379–88 respectively.

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(by B. R. SINGER)

This short bibliography is provided as a guide to relevant aspects of present-day theory and research in the psychology of perception.

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II. HEBB'S WRITINGS ON PERCEPTION

(*a*) Considerable use is made of the present study in:

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17. Hebb, D. O. *A textbook of psychology*. Philadelphia: Saunders, 1958.

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18. Milner, P. M. 'The cell assembly: Mark II.' *Psychol. Rev.*, 1957, **64**, 242–52.
19. Hebb, D. O. 'A neuropsychological theory'. In S. Koch (Ed.), *Psychology: a study of a science*. Vol. I. New York: McGraw-Hill, 1959, pp. 622–43.

(*b*) Short presentations of Hebb's theories are given in Bartley (2) and in:

20. Bugelski, B. R. *The psychology of learning*. London: Methuen, 1956.
21. Hilgard, E. R. *Theories of learning* (2nd edn.). London: Methuen, 1959.
22. Sholl, D. A. *The organization of the cerebral cortex*. London: Methuen; New York: Wiley, 1956.

More detailed studies may be found in Allport (1) and Osgood (11).

(*c*) Criticisms of von Senden and Hebb, or discussions of the problems involved in interpreting the reports of cataract patients, can be found in Gibson (7) and in:

23. Dennis, W. 'Congenital cataract.' *J. Genet. Psychol.*, 1934, **44**, 340–50.
24. Harlow, H. F. 'Learning theories.' In W. Dennis *et al. Current trends in psychological theory*. Pittsburg: Univer. of Pittsburg Press, 1951.
25. Révész, G. *Psychology and art of the blind*. London: Longmans, Green, 1950.
26. Wertheimer, M. 'Hebb and Senden on the role of learning in perception.' *Amer. J. Psychol.*, 1951, **64**, 133–7.
27. Zuckerman, C. B., and Rock, I. 'A reappraisal of the roles of past experience and innate organizing processes in visual perception.' *Psychol. Bull.*, 1957, **54**, 269–96.

(*d*) A theory essentially similar to Hebb's, but developed from a different point of view, is presented in:

28. Hayek, F. A. *The sensory order*. London: Routledge & Kegan Paul; Chicago: Chicago Univer. Press, 1952.

The theories of Hebb and Hayek are examined from a philosophical standpoint in:

29. Hamlyn, D. W. *The psychology of perception*. London: Routledge & Kegan Paul, 1957.

III. EXPERIMENTAL WORK ON ANIMALS

The following is a selection of relevant sources on research with animals:

30. Chow, K. L., and Nissen, H. W. 'Interocular transfer of learning in

visually naïve and experienced infant chimpanzees.' *J. comp. physiol. Psychol.*, 1955, **48**, 229–37.

31. Hess, E. H. 'Space perception in the chick.' *Sci. Amer.*, 1956, **195**, 71–80. (Also in Beardslee and Wertheimer (3) above.)
32. Riesen, A. H. 'The development of visual perception in man and chimpanzee'. *Science*, 1947, **106**, 107–8.
33. Riesen, A. H. 'Arrested vision.' *Sci. Amer.*, 1950, **183**, 16–19. (Also in Beardslee and Wertheimer (3) above.)
34. Riesen, A. H. 'Plasticity of behaviour: Psychological aspects.' In H. F. Harlow and C. N. Woolsey, *Biological and biochemical bases of behaviour*. Madison, Wisconsin: Univer. of Wisconsin Press, 1958.
35. Thorpe, W. H. *Learning and instinct in animals*. London: Methuen, 1957.
36. Weiskrantz, L. 'Sensory deprivation and the cat's optic nervous system.' *Nature*, 1958, **181**, 1047–50.

Further references will be found in Hebb (17), Weiskrantz (36) and Zuckerman and Rock (27).

IV. HISTORY OF THE STUDY OF SPACE PERCEPTION

Studies of the historical origins of nativism and empiricism, the psychology of space perception or earlier discussions of experimental research on persons born blind can be found in:

37. Boring, E. G. *Sensation and perception in the history of experimental psychology*. New York: Appleton-Century-Crofts, 1942.
38. Boring, E. G. *A history of experimental psychology* (2nd edn.). New York: Appleton-Century-Crofts, 1950.
39. Bourdon, B. *La perception visuelle de l'espace*. Paris: Schleicher, 1902.
40. Carpenter, W. B. *Principles of mental physiology* (6th edn.). London: C. Kegan Paul & Co., 1881.
41. Clark Murray, J. *A handbook of psychology*. London: Alexander Gardner; Montreal: Dawson Brothers, 1885.
42. Höffding, H. *Outlines of psychology*. London: Macmillan, 1891.
43. James, W. *Principles of psychology*. Vol. 2. New York: Holt, 1890.
44. Preyer, W. *The mind of the child*. Part II. *The development of the intellect*. New York: D. Appleton & Co., 1898, Appendix C, pp. 286–317.
45. Southall, J. P. C. (Ed.). *Helmholtz's treatise on physiological optics*. Vol. 3. *The perceptions of vision*. The Optical Society of America, 1925, pp. 220–7, 566–7, 593–4.
46. Stratton, G. M. 'The spatial harmony of touch and sight.' *Mind*, 1899, **8**, 492–505.
47. Stratton, G. M. *Experimental psychology and its bearing upon culture*. New York: Macmillan, 1903.
48. Sully, J. 'The question of visual perception in Germany.' *Mind*, 1878, **3**, 1–23 and 167–95.
49. Sully, J. *The human mind: a textbook of psychology*. Vol. 2. London: Longmans, Green, 1892, Appendix B, pp. 330–5.

V. CASE STUDIES IN ENGLISH

Summaries of the work of Latta and Miner may be found in:

50. Carr, H. A. *An introduction to space perception.* New York: Longmans, Green, 1935.

Carpenter (40) describes his own research and that of Critchett. Preyer (44) gives extracts from the cases originally described in the *Philosophical Transactions of the Royal Society.*

For a further report, not mentioned in the text, see:

51. Fisher, J. H. 'Vision learning after successful operation at age 6.' *Ophthal. Rev.*, 1914, **33**, 161–5.

VI. OTHER EXPERIMENTAL STUDIES

A number of experimenters have examined the imagery and space perception of blind persons:

52. Ammons, Carol H., Worchel, P., and Dallenbach, K. M. ' "Facial vision": the perception of obstacles out of doors by blindfolded and blindfolded-deafened subjects.' *Amer. J. Psychol.*, 1953, **66,** 519–53.
53. Bitterman, M. E., and Worchel, P. 'The phenomenological vertical and horizontal in blind and sighted subjects.' *Amer. J. Psychol.*, 1953, **66,** 598–602.
54. Carr, H. 'The influence of visual guidance on maze learning.' *J. exp. Psychol.*, 1921, **4,** 399–418.
55. Cotzin, M., and Dallenbach, K. M. ' "Facial vision": the role of pitch and loudness in the perception of obstacles by the blind.' *Amer. J. Psychol.*, 1950, **63,** 485–515.
56. Drever, J. 'Early learning and the perception of space.' *Amer. J. Psychol.*, 1955, **68,** 605–14.
57. Duncan, B. K. 'A comparative study of finger maze learning by blind and sighted subjects.' *J. genet. Psychol.*, 1934, **44,** 69–95.
58. Erismann, T. 'L'espace de l'aveugle-né.' *Proc. 10th Int. Congr. Philos.*, 1948-9, 907–10.
59. Hunter, I. M. L. 'Tactile-kinesthetic perception of straightness in blind and sighted humans.' *Quart. J. exp. Psychol.*, 1954, **6,** 149–54.
60. Schlaegel, T. F. jr., 'The dominant method of imagery in blind as compared to sighted adolescents.' *J. genet. Psychol.*, 1953, **83,** 265–277.
61. Supa, M., Cotzin, M., and Dallenbach, K. M. ' "Facial vision": the perception of obstacles by the blind.' *Amer. J. Psychol.*, 1944, **57,** 133–83.
62. Sylvester, R. H. 'The mental imagery of the blind.' *Psychol. Bull.*, 1913, **10,** 210–11.
63. Worchel, P. 'Space perception and orientation in the blind.' *Psychol. Monogr.*, 1951, **65,** No. 15 (Whole No. 332).

VII. SPATIAL INVERSION

A related area of experimental inquiry is that in which subjects are provided with spectacles which invert the visual field. For investigations of this, see Carr (50), Stratton (46, 47) and the following:

64. Ewert, P. S. 'A study of the effects of inverted retinal stimulation upon spatially co-ordinated behaviour.' *Genet. Psychol. Monogr.*, 1930, **7**, 177–363.
65. Snyder, F. W., and Pronko, N. H. *Vision with spatial inversion.* Wichita, Kansas: Univer. of Wichita Press, 1952.
66. Stratton, G. M. 'Vision without inversion of the retinal image.' *Psychol. Rev.*, 1897, **4**, 341–60 and 463–81.
67. Werner, H., and Wapner, S. 'The Innsbruck studies on distorted visual fields in relation to an organismic theory of perception.' *Psychol. Rev.*, 1955, **62**, 130–8.

VIII. THE WORK OF PIAGET

For an account of the development of perception in the child, see:

68. Piaget, J., and Inhelder, B. *The child's conception of space.* London: Routledge & Kegan Paul, 1956.

Partial summaries and further references may be found in Scheerer (12) and in:

69. Berlyne, D. E. 'Recent developments in Piaget's work.' *Brit. J. Educ. Psychol.*, 1957, **27**, 1–12.

IX. ADDITIONAL REFERENCES

70. Guillaumat, L., and Girard, G. 'Résultats fonctionnels des opérations de cataractes congénitales.' *Bull. et mém. Soc. franc. opht.*, 1954, **67**, 343–56.
71. Kiss, W. 'Sehschärfe der in früher Kindheit doppelseitig Staroperierten.' *Klin. Monatsbl. f. Augenh.*, 1937, **98**, 523–31.
72. Riesen, A. H. 'Effects of stimulus deprivation on the development and atrophy of the visual sensory system.' *Amer. J. Orthopsych.*, 1960, **30**, (?).
73. Riesen, A. H., and Aarons, L. 'Visual movement and intensity discrimination in cats after early deprivation of pattern vision.' *J. comp. physiol. Psychol.*, 1959, **52**, 142–9.
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75. Weill, G., and Pfersdorff, C. 'Évolution ultérieure des facultés visuelles d'une aveugle-née opérée.' *Strasbourg méd.*, 1937, **97**, 272–5.

INDEX

References to the reports will be found in the Case-List.
Major allusions to topics are indicated in bold type.